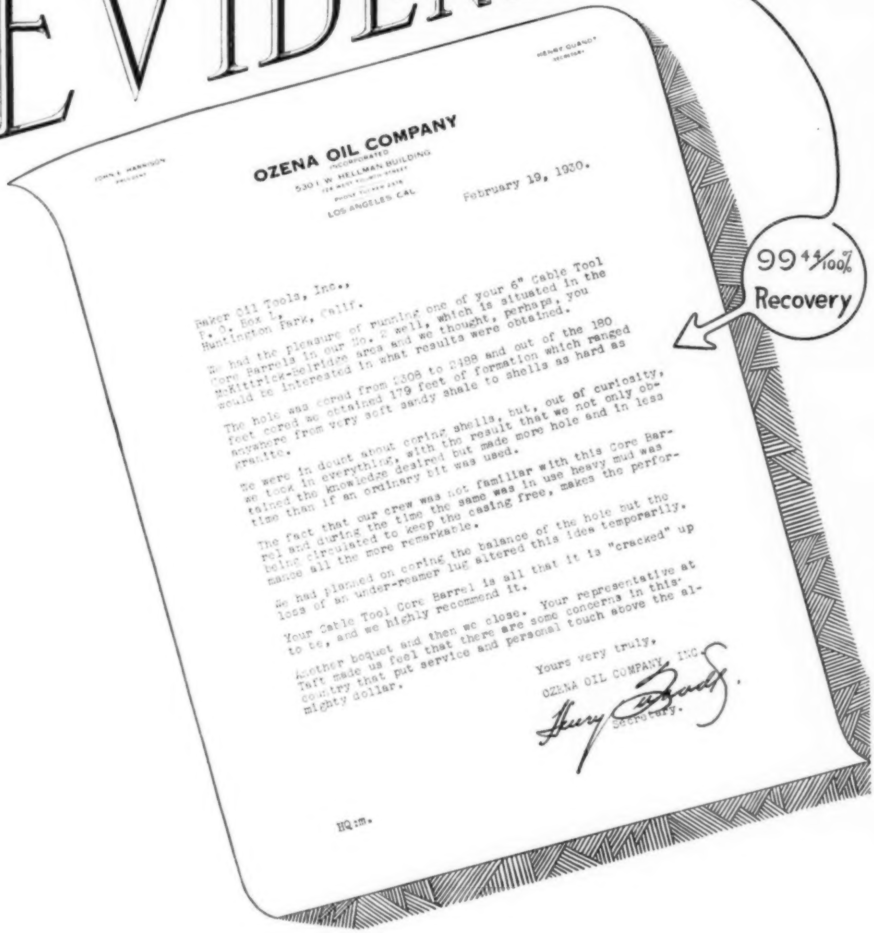
Volume 14 JUNE 1930 Number 6

BULLETIN
of the
American Association *of* Petroleum Geologists

CONTENTS

EVIDENCE



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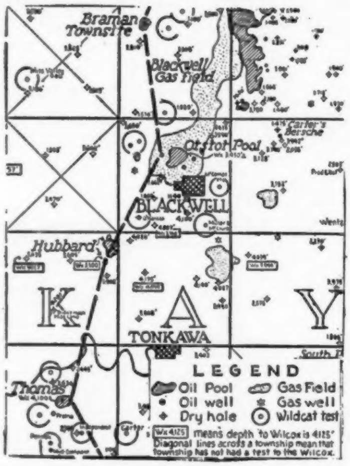

Braman Townsite
Blackwell Gas Field
Carter's Bersche
Otstot Pool
BLACKWELL
Hubbard
K A Y
TONKAWA
Thomas
LEGEND
Oil Pool
Gas Field
Oil well
Gas well
Dry hole
Wildcat test
Wx 4125 means depth to Wilcox is 4125'
Diagonal lines across a township mean that township has not had a test to the Wilcox.

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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BULLETIN

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Volume 14 JUNE 1930 Number 6

CONTENTS

Articles Scheduled for Publication in the July *Bulletin*

Faulting in Southwestern Arkansas

By C. L. RANKIN

Cretaceous and Tertiary Sediments of Kentucky, Illinois, and Missouri

By J. E. LAMAR and A. H. SUTTON

Building of Mississippi Delta

By A. C. TROWBRIDGE

Phases of Sedimentation in Gulf Coastal Prairies of Louisiana

By R. A. STEINMAYER

Geology of Larremore Area, Caldwell County, Texas

By ALBERT WILLIAM WEEKS

Hendrick Field, Winkler County, Texas

By A. L. ACKERS, R. DeCHICCHIS, and R. H. SMITH

Volume 14 Number 6

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

JUNE 1930

GEOLOGY OF PROSPECTIVE OIL TERRITORY IN REPUBLIC OF TURKEY[1]

SHIRLEY L. MASON[2]
Pittsburgh, Pennsylvania

ABSTRACT

The geological conditions in connection with the oil prospects of Turkey are reviewed. Typical regions are described. The Boyabad area represents small isolated grabens here and there in the mountains of Anatolia and Armenia which have been given importance by the presence of oil seepages. The Merefte area, in the forefront of a Balkan overthrust, represents the most favorable area in European Turkey. The Eastern Province area covers the extension of the Mesopotamian structural basin across the Turkish border. The eastern part of this is broken by block faults and complicated overthrusts which give way to great gentle anticlines in the western part. These areas show signs of oil, but the relation of these signs to the structure and stratigraphy leads to the conclusion that development could not be undertaken profitably by foreign enterprise.

INTRODUCTION

There are no producing oil fields within the Republic of Turkey. The geographical position of the country and the presence of seepages have encouraged the belief that fields could be developed. With Roumania on the northwest, Russia on the northeast, and Persia and Iraq on the southeast, Turkey is well bordered by oil-producing countries. The seepages, although numerous in western Anatolia and that part of Armenia remaining in Turkey, are widely separated. Their importance is emphasized by the fact that the regions of similar seepages in the lost provinces of Mesopotamia have since been proved great potential fields.

[1]Read by title before the Association at the New Orleans meeting, March 21, 1930. Manuscript received by the editor, February 13, 1930.

[2]Huntley and Huntley, consultant geologists.

The Turkish government is doing everything in its power to encourage development of all natural resources. Oil production would not only be a source of revenue, but an assured supply within its borders would strengthen its military and economic position. The traditions of the neighboring nations make military defense of paramount importance. The great strides toward modernization made by the Turkish nation under the present régime have correspondingly increased the need for petroleum products. With its own production, further progress would not be dependent on the continuation of foreign imports. The government efforts are spurred by the memory of the failure of the old régime to develop the Mosul area.

As there are not Turkish capital and experience available for petroleum development, the government has offered excellent terms and inducements to foreign oil companies. In this connection the writer had the opportunity to examine any region of Turkey which he thought might have possibilities of commercial production. After visiting the regions selected as most favorable, he concluded that, although some oil might be produced, there was no region in the country that foreign capital could develop profitably.

The following descriptions of several of the regions are of general geological interest, and give an idea of the conditions on which the negative conclusions were based. The three areas selected demonstrate the problems and possibilities of the country. The location of these is shown on the sketch map of Turkey (Fig. 1).

The Boyabad graben is characteristic of conditions in the many prospects in Anatolia and Armenia. These might be considered as representing the hopes of the extension of oil areas of the south Caucasus region of Russia, although a reported seepage a few miles off the coast in the Black Sea is the only indication that could be connected with that zone.

The Merefte area, on the European side, is important because of its accessibility. It is the sole prospect which might be in an outlying remnant of the Roumanian production zone, but Pliocene beds, which form source and reservoir horizons in Roumania, are lacking here.

The Eastern Province area is the northern part of the Mesopotamian structural basin. The fields of Persia and Iraq are on the border of this basin farther south.

The officials of the Turkish Government and of the provinces visited did everything possible to assist the work. Special acknowledgment should be made of the courtesy and hearty coöperation of the

FIG. 1.—Sketch map of Republic of Turkey, showing the location of the areas described.

Vali of Mardin. W. R. A. Weatherhead was associated with the writer on the major expeditions. His assistance, particularly in the Merefte area, where he spent some time prior to the writer's arrival, was invaluable.

BOYABAD GRABEN

The greatest number of reported oil prospects lie in what might be termed the "graben and horst region" of Anatolia. This includes northern and central Anatolia and western Armenia. Most of these prospects were not visited, but complete files of all earlier reports were available. The reports were of widely varying accuracy and value, but in practically all of them the probable presence of this typical structural condition could be recognized, although no report described it in so many words. The cross section of Anatolia by Oswald,[1] which was used as a base for Figure 2, confirmed this interpretation, at least for several localities. Another assurance was found in the areal maps of the country, which show the Tertiary sediments in these prospects as small, abruptly truncated patches. The prospects near Baiburt, Erzeroum, and Lake Van

[1]Felix Oswald, *Geology of Armenia* (privately printed in London, 1908); *Handbuch der regionalen Geologie,* Vol. 3, *Armenia* (Heidelberg, 1911).

are among the oil areas in this group, but the Boyabad area was studied in some detail and is given as the type for these and similar occurrences.

LOCATION

The Boyabad graben lies in the valley of Geuk Irmak River, 50 miles south of the Black Sea port of Sinope. Although there are hills of considerable relief in this valley, the topography conforms closely

FIG. 2.—Diagrammatic structural section, after Oswald, slightly modified by writer in areas studied. Qp = Pleistocene; Tm = Miocene; Te = Eocene; K = Cretaceous.

enough to the structure to sink this area well below the surrounding country. As a result, the climate is definitely warmer and drier than in the regions around it. The graben is named for the town of Boyabad at its southern edge.

STRATIGRAPHY

Place names were given to the formations from type localities. An age classification has been adopted to clarify their relationship. This was done without fossil evidence, but it is believed that the comparative ages given illustrate conditions more clearly than could have been done otherwise.

PALEOZOIC

Dume schists. Schists of probable sedimentary origin, with irregular quartz veins. On south, extend indefinitely back into the mountains, evidently thousands of feet thick; on north, a few hundred feet seem to overlie serpentine

Serpentine. A few hundred feet exposed on the south overlying schists. Northerly exposure much greater and indefinite. Age relationship with schists uncertain

MESOZOIC

CRETACEOUS

Jumaa Aksham Dagh limestone. Very hard gray limestone forms cliff 100 feet high overlying older schists

CENOZOIC

TERTIARY

EOCENE

Boyabad limestone. Yellow and brown granular massive limestone 300 feet thick

Erking Viran shales. Dark gray to black shales, 200 feet exposed in highly faulted area. Dip 75°. Indurated and fractured

Nafte sandstone. Very hard yellow sandstones with pebbles of Cretaceous limestone. Vertical, contorted, and faulted. Thickness estimated at 100 feet

OLIGOCENE

Martlu shales. Yellow-brown shales with thin sandstones. Beds vertical or nearly so. Massive sandstones in highest and lowest beds exposed indicate reduplication; allowing for these, 7,000 feet exposed

MIOCENE

Yubanti marls. Gray marls in small, heavily faulted area. Dips less than 45°

PLIOCENE

Chaughlar conglomerates. Sandy conglomerates and sandstones. Thickness indefinite—probably exceeds 20,000 feet. Gentle dips

QUATERNARY

Yuruk basalt flow. Maximum thickness, 300 feet. Overlies Pliocene beds

Terraces. Silts and gravels. Slightly consolidated; no marked tilting

STRUCTURE

The structure is a graben in the most restricted sense. There are not only faults in step series bordering both long sides, but cross faults at the ends lowering the younger beds below the older series. All the major faults are formed by a series of comparatively short faults. On the northern side the major fault zone is, in places, more than a mile wide. The arrangement of the beds and the position of the major faults is shown by the diagrammatic section included in Figure 3. It will be seen that all but the youngest beds involved in these fault blocks have been violently tilted and folded, and there is every reason to believe that this twisting of the older beds is continued under the areas covered by beds with gentle dips.

The movements along the fault planes evidently took place repeatedly through the Tertiary epoch, and there is a slight evidence of southward tilting in the Quaternary. The erosion of the Quaternary lacustrine terraces and fan deposits is probably due to a lowering of the outlet rather than to any local structural movement.

The faulting is the only structural feature of importance. There is a slight doming of the Chaughlar conglomerates north of the junction of Gova Dere and Geuk Irmak, and there are probable minor folds in

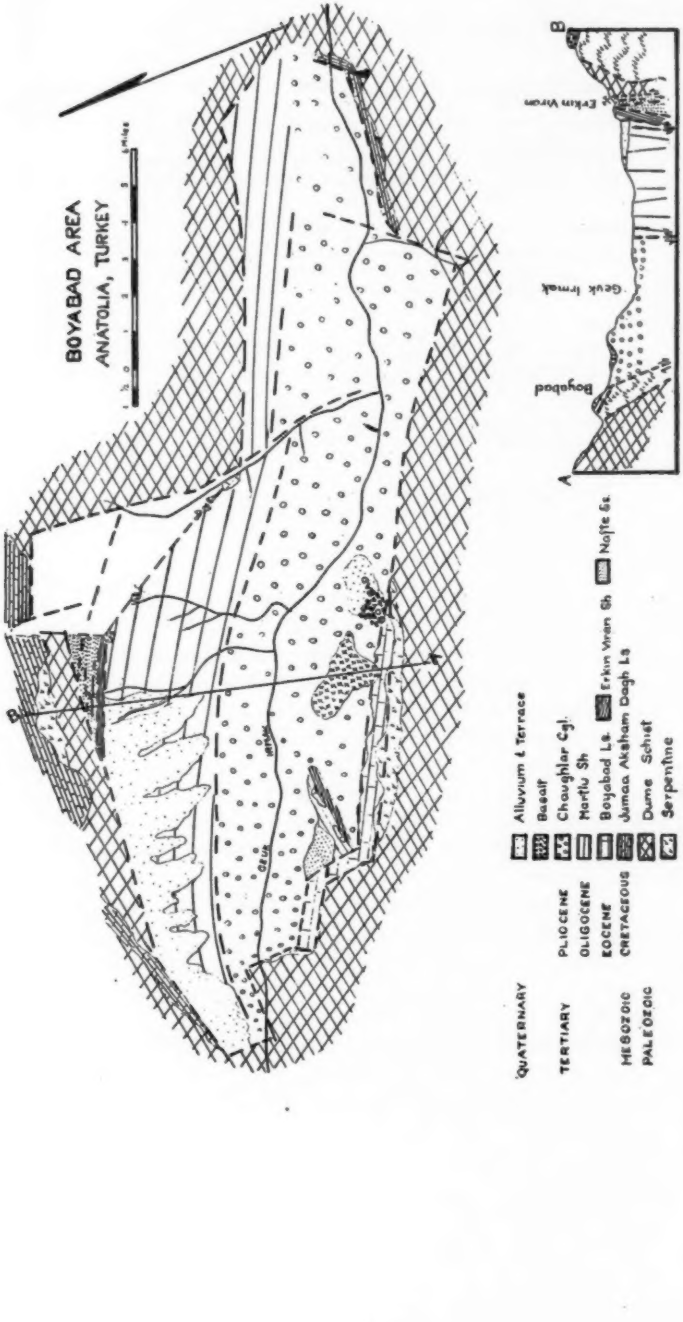

FIG. 3.—Areal geology and section of Boyabad graben.

the Yubanti marls, but these are of no more interest than the many minor faults throughout the area.

OIL POSSIBILITIES

There is a seepage of paraffine-base oil, resembling the heavier portion of a high-grade crude, from a small fault in the northern zone of major faults. It is probable that the source beds of the oil are not exposed. The Erking Viran shales might, if they escaped metamorphism, have some significance in relation to oil. With these as the highest possible source, there is no place outside of the immediate narrow fault zone where they could be expected at a depth of less than 10,000 feet. These beds are entirely local, not occurring recognizably in any exposures outside of the graben. There is only the one small seepage in all of this extremely faulted region. These facts seem to indicate a very small potential source, and could not justify exploratory drilling to the necessarily great depth.

There is a possibility that a light drilling machine working along the faults might find a brecciated zone with some production. Such development might be of interest to local people, but there is nothing sufficiently promising to justify serious consideration by foreigners.

OTHER GRABEN AREAS

The available descriptions of the other prospects of this type indicate that they are smaller in area than the Boyabad graben and in some places the area of sedimentary rocks in the graben is much broken up by igneous rock. The seepages do not occur in connection with the wrinkles dignified by the name of anticlines and are probably governed by faults. Drilling was done in some of the prospects during the Russian occupation without encountering more than traces of oil. These negative factors, combined with the remoteness of the region from the sea, accessible only over mountain roads, were considered satisfactory evidence that foreigners could not find development profitable, and the areas were not examined.

EUROPEAN OVERTHRUST AREA

The accessible position of the Merefte area on the western coast of the Sea of Marmora (Fig. 1) and the fact that there has been a definite attempt at development there, give that region considerable importance. The area lies about 100 miles west-southwest of Constantinople in European Turkey. It includes the strip of foothills and rolling uplands lying between the mountains and the shores.

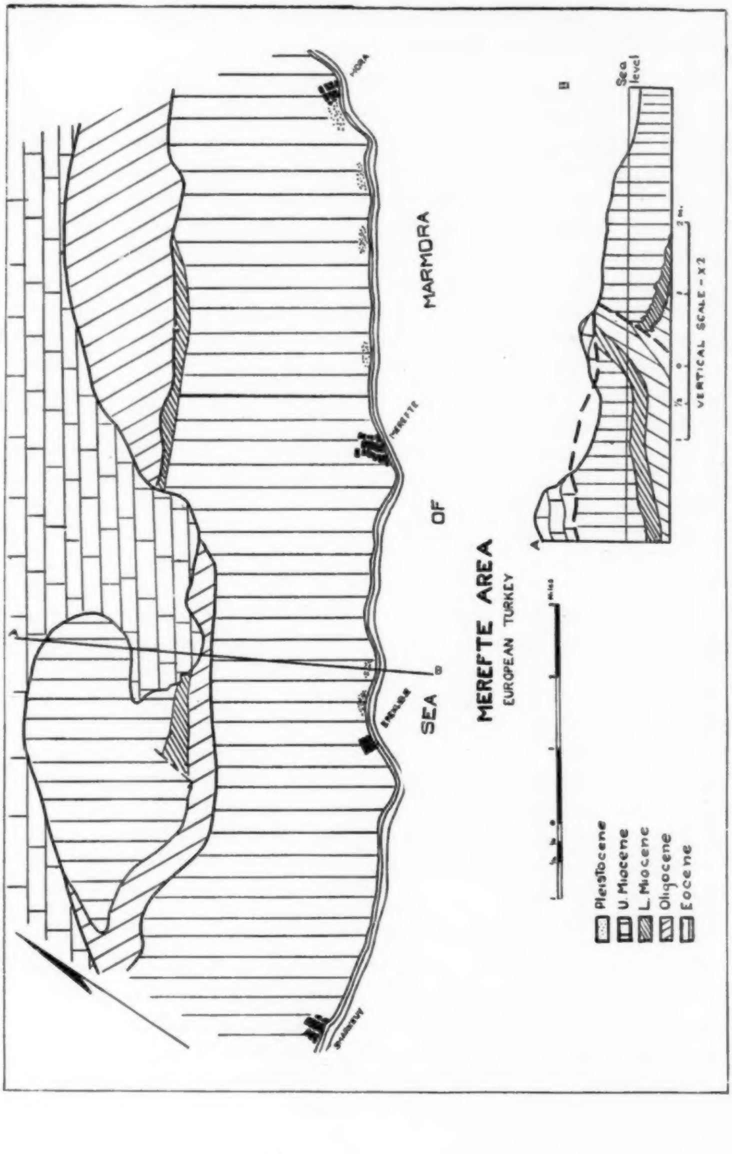

FIG. 4.—Areal geology and diagrammatic section of Merefte area.

STRATIGRAPHY

There has been enough work done to make it possible to describe the formations by age names with considerable assurance.

EOCENE

Hard white limestone. Several hundred feet exposed in overthrust sheet. Normal thickness greater

OLIGOCENE

Blue shales and thin hard sandstones. Four thousand feet exposed. Total thickness unknown, because of faulted contacts. In southern part, some massive sandstones and hard conglomerates

MIOCENE

Probably all Sarmatic, although lower part may be Helvetian and Tortonian

Lower series. Five hundred feet exposed. Bright green and purple clays with few sandstones. Includes 40-foot group of dark clays with lignitic streaks and hard limestones.

Upper series. Two thousand feet. Drab, red, and green-gray clays and sandstones with two limestone beds in northern part of area. Above these, massive gray soft sandstones under white to yellow friable coarse sandstones with some grits and sandy clays. All beds vary laterally in color and lithology. Limestones, where present, only markers

PLEISTOCENE

Hora conglomerate. Hora conglomeratic limestone with many *Ostrea.* Six hundred feet above sea at Hora. Dips 15° inland

Mactra limestone. Remnant of old terrace 100 feet above sea near Ereklidje. Dips 8° inland. Limestone argillaceous, with many *Mactra* shells

Terraces. Ereklidje terrace probably younger, but traces of Hora terrace lower in that direction and these may be local phases of some original terrace. Tilted terraces are not surprising in this area of frequent earthquakes

STRUCTURE

The cross section included in Figure 4 shows diagrammatically the structural arrangement of the region. Great overthrust faults extend parallel with the coast and thrust toward the sea. These bring Oligocene beds over Miocene, Eocene beds over Oligocene, and, in some places, Eocene over Miocene.

In front of this fault zone the Miocene beds are wrinkled in innumerable small folds. These folds are irregular in size and direction, but are somewhat more numerous in the northern half and tend to parallel the faults and the coast. Their shape is irregular, but there is a tendency for the steep flank to occur on the side away from the major faults. There are many small faults in this wrinkled area, but not any of great importance. The type of movement which caused this minor fold,—low-hade overthrust acting more forcibly on the upper beds than on

those in depth,—makes it very doubtful that the surface folds continue any great distance downward.

OIL POSSIBILITIES

Two kilometers up Merefte Dere (creek) there is an outcrop of soft massive sandstone which, if broken, gives a faint odor of kerosene. One and one-half kilometers beyond, in the valley alluvium, but apparently from a similar sandstone, there is a slight bubbling of inflammable gas. About 3 kilometers up Hora Dere, nine small shallow holes were drilled in 1900-1902. One of these was reported to have made 14 barrels of oil (supposedly per day). It is completely surrounded by tests drilled within a few yards in which nothing but traces were found.

It had been hoped after a study of the earlier reports that the shallow showings would be found to overlie deeper horizons capable of profitable production. Unfortunately the deeper horizons are not of a type which forms oil source beds. A check on this sterility is furnished by the lack of oil showings at the outcrop of the lower beds and along fault lines cutting these beds at depth.

The upper formation has a small thickness of possible source beds. It is probable that only a little oil was formed and that has been widely dispersed. There are no major structures, and the minor fracturing and lack of effective cap rock has permitted the oil to be disseminated all through the column. As a result, test holes would probably encounter showings of oil or gas, but the chances of profitable production are negligible.

EASTERN PROVINCE AREA

The Eastern Province area forms a strip about 50 miles wide extending about 100 miles along the border of Syria and Iraq. The western limit of this area is 700 miles southeast of Constantinople, and approximately 300 miles east from the coast of the Mediterranean at the Bay of Alexandretta. The part of the area west of the Tigris covers the edge of the broad Syrian plain on the south, separated by the escarpment of the Mardin hills from the high, gently rolling limestone region of the north. East of the Tigris, the sharp escarpment of Judi Dagh separates the flat valley on the south from the decidedly mountainous area beyond.

AREAL GEOLOGY

The writer's interpretation of the areal geology of the region is shown in Figure 5. This has been somewhat modified, owing to the fact that

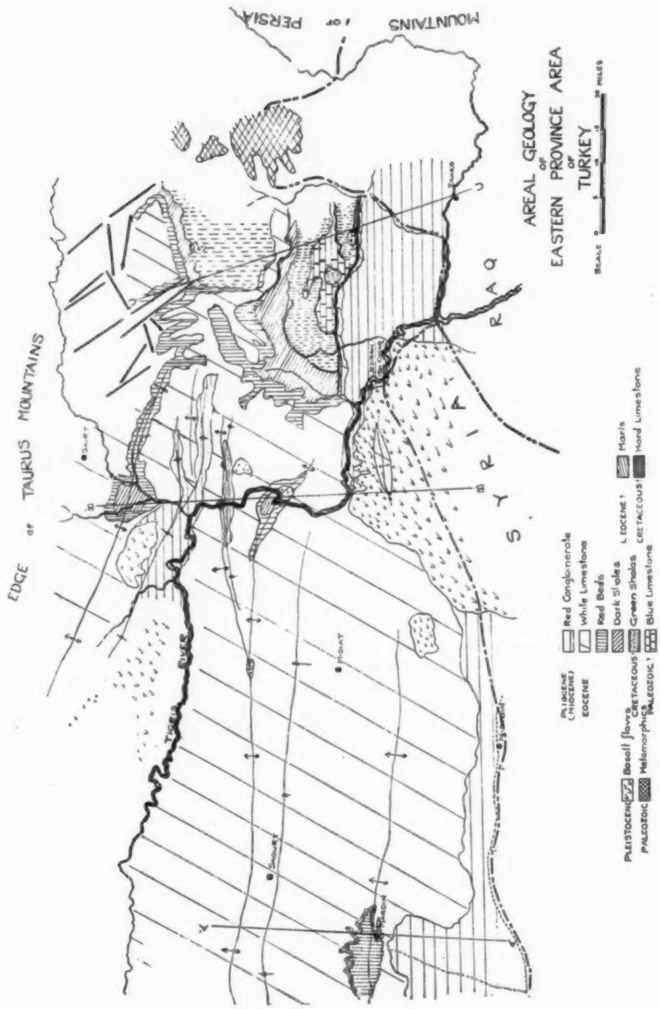

FIG. 5.—Areal geology of Eastern Province region

the topography on the base map was incorrect in some areas. It is believed, however, that the error from this cause is slight.

The map shows that the greater part of the area is overlain by Eocene limestone. The red conglomerate of the Pliocene, although marked in the same way on both sides of the great Jezirah basalt flow, is more typically a continuation of the Pliocene Bakhtiari conglomerate of the Mosul area, on the eastern side. The Pliocene area on the western side is characterized by reddish sandy clays without noticeable conglomerates. As the formations in the two areas bear the same relations to other rocks, they are marked here as identical. In the other case of doubtful correlation, the marls and dark shales of the Eocene have been distinguished by different markings.

STRATIGRAPHY

PALEOZOIC

Metamorphic rock. Schists with quartz veins. Not examined closely. May be pre-Cambrian

Blue limestone. Several hundred feet exposed, with slates, in overthrust. Hard massive limestone, of definite dark blue color, with thin white calcite streaks. Resembles Mississippian limestone of western Asia Minor and Persian Mountains. Fossil traces suggest *Fusilina*, which would make age Pennsylvanian

MESOZOIC

CRETACEOUS

Hard limestone. Two hundred feet of hard, fine-grained, gray limestone exposed in center of anticline near Mardin. No fossils found or reported. Earlier classification as Cretaceous satisfactory from position in section

Greenish shales. Gray and green shales with thin marly limestones. In certain areas shales darker, purple and bluish, showing considerable slaty cleavage. Thickness probably more than 1,000 feet. No fossils, and most contacts faulted. From lithologic character and apparent relationship with other formations seems Mesozoic and probably Cretaceous

CENOZOIC

TERTIARY

EOCENE

Dark shales. Gray to black, marly to fissile, shales. In places with many thin-bedded limestones; in other places, sandstones. Considered lower Eocene from similarity with oil source beds farther south in the Mesopotamian basin. Similar in lithology, in position with regard to other beds, and in being a probable source of petroleum in local seepages; but differs in lime content, being more marly than southern type. Reddish areas in shale due to burning manjak outcrops. Manjak veins from desiccation of petroleum common in these shales. Further manjak outcrops and oil seepages in the Red beds above these shales and supplied from them. Maximum thickness found, 750 feet

Marls. Near Mardin, above Cretaceous Hard limestone, gray marl, with white limestone and light yellow shale, forms 200-foot section.

Probably represents not only the Dark shales but also the interval including part of the Red beds above and at least part of the green shales below. Marls of this section lighter-colored and with greater lime content than Dark shales. Description by Ainsworth,[1] an earlier traveler, as carbonaceous shale, probably due to the carbonaceous films common in bedding planes

Red beds. In eastern exposures, clays and argillaceous sandstone of uniform, intense dark reddish color. Iron in beds formed great blocks of slag where manjak burned. Farther west, clays more marly; form alternating red and white marls and sandstones; limestones appear and thicken rapidly toward the west. This change of facies and increase of limestone probably accounts for disappearance of Red beds, as such, in Mardin region. Possibly represented by lower part of massive White limestone

White limestone. Most prominent horizon in region. Uniformly light-colored, grayish white to yellow, but varies from smooth, hard, and thin-bedded to massive, granular, and irregularly eroded. Variation lateral as well as vertical, so that individual horizons cannot be traced. Middle and upper Eocene fossils found in certain localities. Some exposures in northeastern area, where involved thrusting occurs, uncertainly correlated, but probably in this horizon. Bed near base of this group weathering in pits suggested as the possible reservoir. With known differences in texture, favorable reservoirs might be developed anywhere in the group, but such development improbable. No oil or sign of oil seen or reported from this group

OLIGOCENE (Lacking)

MIOCENE

Gypsum beds. Reported from upper Tigris Valley. Lower beds of red conglomerate resemble Upper Fars (*Miocene*) in Mosul area, but probably of Pliocene age

Asmari or Euphrates limestone of lower Miocene age, great reservoir bed of Irak and Persia, not present here

PLIOCENE

Red conglomerates. Conglomerates with limestone pebbles and some red and black chert, soft coarse sandstones, and reddish clays. Correlated by character and location with Bakhtiari conglomerates of Mesopotamia. These exposed in eastern area. Reddish clays of western area considered of same age

PLEISTOCENE

Basalt flows. Black, olivine basalt in wide flows. Ranging in thickness from 20 feet along the Tigris to more than 200 feet in the interior of the major flow. Ranges of hills in flow area may mark location of source drifts. No flow structures noticed

Terraces. Highest Tigris terraces without basalt pebbles probably formed prior to flow

STRUCTURE

The region lies in the northern part of the tectonic basin of Mesopotamia. This basin is flanked by the Persian Mountains on the east, the Arabian shield on the west, and the Taurus Mountains of Asia

[1] N. F. Ainsworth, *Travels in Asia Minor* (John W. Parker, London, 1842). Quoted by Oswald, *op. cit.*

Minor on the north. Active movement is indicated by the Persian Mountains and the Taurus Range. Thus the long overthrust folds of eastern Iraq parallel the northwest-southeast mountain chains of Persia, though the folds in this region in southeastern Turkey follow the east-west trend of the Taurus. Of the two thrust forces, the Persian was stronger; not only is its opposing folded belt wider and with sharper folds, but there is a marked increase in the strength of folding of the Taurus belt in the east, as it approaches the Persian zone.

The region covered here is best described by dividing it into three structural zones: western, central, and eastern. The three diagrammatic sections (Fig. 6) show typical examples of each of these zones. Of course

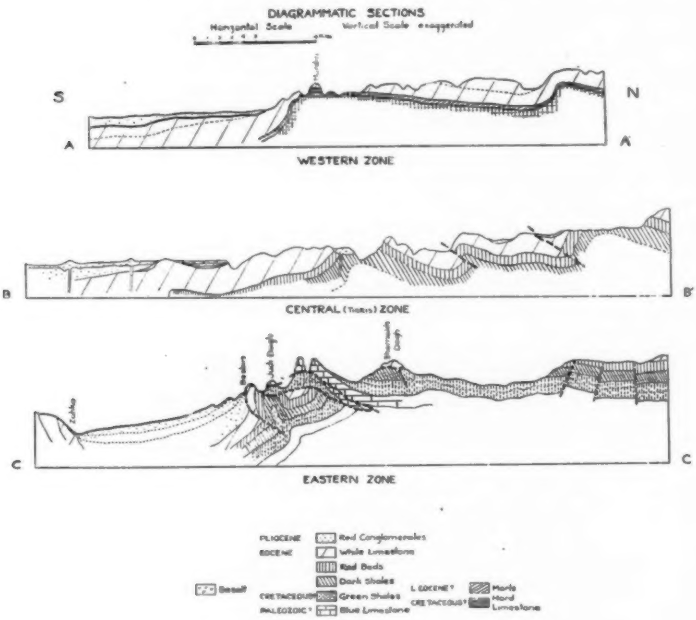

Fig. 6.—Sections across Eastern Province region

the entire region is structurally continuous in the direction of trend and in the origin of the major forces, but there has been enough variation in the intensity of these forces to result in different sections characteristic of the three zones.

The western zone is represented by section *A-A′*, cut through Mardin, in the extreme western end of the region. This zone extends approximately 50 miles east of Mardin, to the western edge of the southern basalt sheet.

The two anticlines shown here extend through the entire zone. The southern limb is decidedly steeper on both, and in the locality of the section there may be a very slight overthrust at points of steepest dip, —although a diligent search found no proof.

In contrast to the other sections, the anticlines here are broad and gentle. The section was drawn through this locality in order that the contrast might be shown where it is least marked. In the other part of this zone the anticlines are more gentle. North of Nisibin the asymmetry of the southern anticline is restricted to a small flexure 5 miles south of the axis. Still farther east, although the asymmetry is persistent, the anticline is so flattened that it might be described as a monocline.

In connection with these folds are small minor flexures, ordinarily in a transverse direction. They occur most noticeably on the southern side beyond the line of steepest folding. They are related to the steep folding, being most numerous where it is greatest, and form a series of small gentle noses from the side of the greater structure.

The central zone corresponds approximately with the basalt and the region north of it. The structure of this zone is illustrated by section *B-B′*, which is practically a section along the north-south stretch of the Tigris and Bohtan Su. In this section the structures are more sharply defined and more numerous than they are in the west. Several have been sketched here as broken by overthrust faults. Because of the covering of unconformable Pliocene strata in the frontal valleys, these faults could be proved only by accurate measurements of sections throughout the region. All that can be said definitely is that they are forcibly indicated during a rapid traverse. Their insertion in this section aids in fixing the type of structure characteristic here, in contrast to that of other zones.

The prolongation of the Mardin anticline is shown here by an axial outcrop through the basalt sheet. Because of this cover, the precise form of the structure is not positively known. It is believed to be gentle, not only because the series of structures show increasing gentleness toward the south away from the source of the thrust, but because, where the axial area is uneroded, as here, pronounced anticlines in this region have corresponding topographic elevations, which the basalt could not mask.

The locations of the thin feeding dikes of the basalt flows are supported by the slight evidence of ridges of exceptional basalt thickness. They are marked in Figure 6 to show the nature of the flows, as well as to show that the probable sources were long "cracks," rather than circular necks. As drawn, these show a different type of earth movement from the characteristic thrusting. Although not proved, this is not impossible, as the basalt appeared later than any of the beds involved in the thrusting movement. There may have been such "cracking" to relieve tension caused by a slight settling of the great basin after the earlier compression had formed the folds.

The southern zone comprises the remainder of the area, and is illustrated by section *C-C′*. Near the center of the section, coinciding with the line of Judi Dagh, several lines of overthrust are close together in their outcrop. The structure shown below these thrusts is the best explanation possible from the exposures seen on a single traverse.

The section shows that the impelling forces are not due north-south. The block faulting indicated at the north end connotes an area of less compression than that of Judi Dagh. It is probable that these thrusts originated farther east. The isolated limestone on Shernakh Dagh was pushed into place from the east or from the west,—probably from the west.

The north end of the section is generalized. Viewed from a considerable distance, the area appeared to be formed by great blocks separated by faults of small throw. It could be ascertained, even at a distance, that this northern region is not heavily folded nor thrust. The structural condition was deemed best illustrated by diagrammatic vertical faults.

The region as a whole is crossed by structures with their long axes extending east and west. These structures are more numerous, and more sharply folded and broken toward the east. For the purposes of description, the region has been divided into three zones, although there are no definite boundaries, and individual structures continue from one zone to another, changing their form gradually. There are indications of a curious structural habit causing a gentle anticline to finger out into a prolongation of several sharper anticlines.

OIL POSSIBILITIES

The region lies, as stated previously, on the northern edge of the Mesopotamian basin. Oil has been found in great quantities in the similarly folded belt along the eastern edge of this basin. The producing fields range from 100 to 600 miles southeast of this area.

Seepages of live oil are found here, at Kerbent, west of the Tigris. On a line about 100 yards long, there are three seepages of a few blobs of heavy, black, liquid crude floating on salt-water pools. They come from the middle of the Red-bed section near the axial area of an anticline.

Veins of manjak, locally considered coal, are fairly common, particularly in the eastern area. These occurrences are in the Dark shales and in the Red beds above them. Some veins follow the bedding planes, but most of them break irregularly through them. The manjak is smooth, dull black in color, and has a conchoidal fracture, resembling certain grades of cannel coal.

In spite of these oil indications, the chances for large production in this region are not good. This opinion is formed notwithstanding the fact that the writer's work among the long overthrust folds of the Mosul area prevents his regarding complicated structures as condemnatory.

The Asmari limestone which forms the producing "sand" of the fields in the Near East is lacking here. Properly porous zones might be present in the enormous thickness of the White limestone, but there is no way of proving their presence or of foretelling the location of such zones.

In the western area, where the probable source beds have sufficient thickness to be of interest, they are much broken and do not have the necessary cover. In their most favorable region these beds have greater lime content than is desirable. This probably accounts for the small number and small size of the manjak veins in a region so thoroughly exposed.

Farther west, where these source beds are under cover and involved in more favorable structures, they are much thinner and the detrimental lime content has increased. In part of this western area, the anticlines are too gentle to be effective in accumulating oil. One of them covering more than 100 square miles has no point of marked elevation except where erosion has cut through the source beds. In no part of this western area is there any indication that oil has been formed.

Development in this region would not be profitable to foreign oil companies unless production comparable with that of the fields on the south were obtained. If the optimum conditions as to source beds, structure, and cover, present anywhere in this region, could be found together in one locality, that locality would have good chances of producing oil, but not of the great production characteristic of the Persian

and Iraq fields. As these optimum conditions are found each in a different part of the region, even very small production is improbable.

CONCLUSIONS

The many indications of oil in the Turkish Republic are not found in conjunction with areas geologically favorable for the formation and accumulation of oil in commercial quantities. This is partly due to the fact that the remoteness and inaccessibility of most of the prospective areas would require large production to make development profitable. However, it is doubted whether even government undertaking, without the necessity of profit, could discover enough oil to be of military or economic importance.

ORIGIN OF OIL AND ITS RESERVOIR IN YATES POOL, PECOS COUNTY, TEXAS[1]

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ABSTRACT

The Yates pool in Pecos County occurs on a structural and depositional "high." Porosity in the top of the "Big lime" was developed during periods of subaerial exposure. The oil originated from accumulations of organic material in the deep Crockett County basin east of the pool.

INTRODUCTION

The Yates pool is the best known example of the larger West Texas oil fields. Two very interesting reports on the geology have appeared within the last few months.[3] The purpose of the writer is to consider the origin of the oil and the reservoir rather than the general geology of the pool. That part of the subject matter which deals with the origin of the oil was originally suggested to the writer by the late C. C. Nutting, professor of zoölogy at the University of Iowa.

STRATIGRAPHY

The stratigraphy of the field is shown in the accompanying cross section (Fig. 1). The formations encountered in drilling wells in the field are classified as Cretaceous, Triassic, and Permian. The Cretaceous is divided into an undifferentiated upper limestone series and a lower basement sand. The Triassic consists mainly of shales and sandstones with considerable gravel. The known Permian is divided into two parts, the evaporites and the "Big lime." The evaporite section includes an upper salt series, missing over the top of the "high," the Yates sand, and a lower anhydrite and salt series. This lower series is tentatively correlated with the Whitehorse on the eastern side of the

[1]Read by title before the Association at the New Orleans meeting, March 22, 1930. Manuscript received by the editor, February 13, 1930.

[2]The California Company subsurface laboratory.

[3]G. C. Gester and H. J. Hawley, "Geology of the Yates Pool," *Structure of Typical American Oil Fields*, Vol. II (Amer. Assoc. Petrol. Geol., 1929), pp. 480-99.
R. V. Hennen and R. J. Metcalf, "Yates Oil Pool," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 12 (December, 1929), pp. 1509-56.

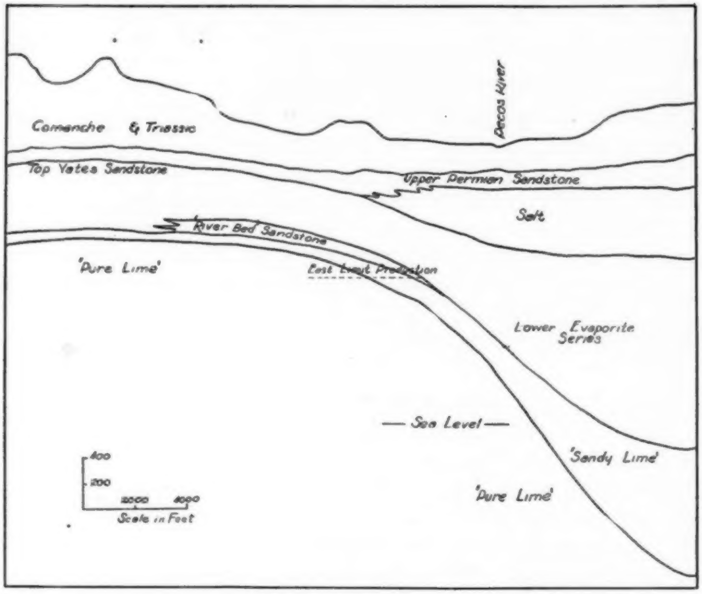


FIG. 1.—Northeast-southwest section across east edge of Yates pool.

basin. On the eastern edge of the pool, the lower 150 feet or so of the lower anhydrite is very sandy and the name "River bed" sandstone is locally applied to this part of the section. The "Big lime" series which underlies the evaporites is divided into an upper sandy phase ranging from 85 to 145 feet in thickness, with the "brown lime" horizon at the top, and a lower non-sandy phase, often referred to as the "pure lime."

The pool occurs on a pronounced, although slightly irregular, dome, with the main production coming from the upper part of the "Big lime" and from the overlying "River bed" sand. The steepest dips are toward the north and east, where the beds slope off into the Crockett County basin. Dips in the other directions are fairly gradual. The eastward divergence of the upper Permian beds causes an increase of almost 2,500 feet in the thickness of the section within a few miles of the crest of the field. About 700 feet of this thickening is due to the inwedging of the upper salt series and the overlying Permian Red-beds, about 1,000 feet is due to an increase in the lower anhydrite, and 800 feet is due to an increase in the "sandy lime." The universal convergence

of formations over the pool, above the "pure lime," suggests that deposition occurred on a contemporaneously growing structure.

The major porosity occurs in the limestone, which in places is almost cavernous, and is limited to the higher parts of the dome. Edge water and some oil are encountered in the surrounding wells, but because of the comparatively insignificant porosity, the flow is much smaller than that in the center of the pool. The thickness of the porous zone in the pool proper is unknown because very few wells have penetrated more than 225 feet below the top of the "brown lime."

The sedimentary processes that produced the Yates pool are still operative in the sea, and the interpretation of the history and origin of the Permian structure is aided by an understanding of what is taking place under similar conditions at the present time. Five factors were important in the development of the Yates pool. These are the formation of the structure, the deposition of the limestone, the development of the porosity, the origin and accumulation of the oil, and the formation of the impervious trap.

STRUCTURE

The origin of the structural feature localizing the Yates pool is still unknown. It may have been a fold, a fault, or some topographical feature such as a buried mountain. Possibly it represents the settling of a basin along the edge of a positive area. Since its inception, natural processes have perpetuated and even accentuated the original dips. Several periods of folding are recognized in the upper Permian and post-Permian deposits.

ORIGIN OF THE LIMESTONE

Limestone can be deposited in several ways. Most marine limestones contain elements of both organic and inorganic origin. The warm, shallow, tropical, and subtropical seas are essentially saturated with calcium in the form of calcium bicarbonate ($Ca(HCO_3)_2$) and other soluble calcium salts. Calcium carbonate ($CaCO_3$) is practically insoluble in sea water. An increase in the carbon dioxide content of the water increases its ability to dissolve limestone. Cold water is capable of retaining more CO_2 than warm water; therefore, the colder, deeper parts of the ocean are not saturated with calcium because of their high carbon dioxide content, although they may contain a greater proportion of calcium than the shallow waters. With a decrease of carbon dioxide in solution calcium carbonate is precipitated directly from the bicarbonate

solution to form limestone. Agitation, aeration, and increased temperature are the main mechanical processes causing the loss of CO_2. Some biochemical processes, such as photosynthesis, also remove CO_2. Lipman[1] has recently shown that bacteria are not important agents in the precipitation of calcium carbonate under normal conditions.

All of the foregoing causes of limestone precipitation are active at or near the surface. The limestone granules which are formed settle to the bottom if the water is warm and shallow. If it is deep and cold, the granules are apt to be dissolved during downward migration. For this reason, there is a tendency for the deposits to build up more rapidly on the submarine "highs" than in the basins. This is not true in areas of clastic deposits, but only in those regions in which limestone is the main sediment. With an initial difference in elevation of only a few hundred feet, almost all of the $CaCO_3$ is deposited on the higher surface; and, with gradual subsidence, the higher areas continue to grow upward toward the surface while the lower areas sink with the bottom of the basin. The limestone muds and sands washed over the edge of the elevated banks is either dissolved or forms a talus slope corresponding with the angle of rest.

Marine biologists report that limestone-secreting organisms are more abundant on the shallow banks and littoral beaches than in the deeper submarine channels and basins. Light, temperature, currents, and the type of sedimentation are four of the main ecological factors that control this grouping. Many organisms require light in their life processes. Plants are more directly dependent on it than animals.[2] The depth to which photosynthesis takes place in sea water is determined by the latitude and by the turbidity. It varies in the temperate zone from 18 to 75 fathoms. Since animals are entirely dependent, either directly or indirectly, upon plants for carbohydrates and proteins, the photosynthetic depth serves as an efficient limit to the maximum development of animal life. Forms that live in the deeper, dark parts of the sea are very interesting zoölogically, but they are not abundant enough to affect the character of their environment, as do the limestone-forming animals on the shallow banks.

The temperature of the water is another important factor in marine life. There is only a slight seasonal change in the temperature of sea

[1] C. B. Lipman, "Further Studies on Marine Bacteria," *Carnegie Inst. of Washington Pub. 391* (1929), pp. 233-48.

[2] H. W. Harvey, *Biological Chemistry and Physics of Sea Water* (Cambridge, 1928).

water, and the range through which any marine form thrives varies within narrow limits. Vaughan[1] draws the boundary between shoal- and deep-water coral faunas along the 22.8° C. bottom-temperature isobathytherm. This limit approaches the surface very rapidly as followed outward from the equator. He finds that the available evidence indicates that in the tropics true coral reefs are limited to depths ranging from 37 to 46 fathoms. The optimum temperature for all the main limestone-depositing forms is above 20° C. Drew[2] reports a drop of more than 9° C. in the upper 200 fathoms off the Bahama Bank, which puts the temperature at that depth below the necessary 20° C. At greater depths the limestone-secreting organisms have difficulty in retaining the calcium necessary for growth.

Currents and waves are important in limiting the life zones to the upper waters of the ocean. They transport food, remove débris, and lower the thermoclinal surface. Broad shallow lagoons without good water circulation become depleted in food, develop toxic properties, and produce depauperate faunas. On muddy bottoms the waves may cause the burial of sessile forms. Conditions of life are most favorable where the edges of the banks and reefs are protected by marine algae, massive corals, or hard reef rock. Many of the algae and some of the corals grow best above the base of constant wave action. Most of the sessile forms which wait for the water to bring them food occur in the zone of breaking waves.

Sessile and attached forms are favored by the absence of clastic deposits and are aided by the presence of a firm foundation on which to attach themselves. The absence of attached forms, especially algae, decreases the food supply for the rest and limits the number of individuals found in a given area. The optimum conditions for marine life here listed are those existing on the tops of the shallow banks and littoral bars. Twenhofel[3] remarks that the bottoms at depths less than 100 fathoms support a greater abundance of life than any other part of the ocean bottom of equal area. Johnston[4] limits this depth to 50 fathoms. Solid bottoms at shallower depths are densely carpeted with both plants

[1] T. W. Vaughan, "Corals and the Formation of Coral Reefs," *Ann. Rept. Smithsonian Inst.* (1917), pp. 189-277.

[2] G. H. Drew, "On the Precipitation of Calcium Carbonate," *Carnegie Inst. of Washington Pub. 182* (1914), pp. 35-38.

[3] W. H. Twenhofel, *Treatise on Sedimentation* (Williams and Wilkins, Baltimore, 1926), pp. 609-10.

[4] J. Johnston, *Introduction to Oceanography* (Williams and Wilkins, Boston, 1923), p. 89.

and animals, and the waters above such bottoms are equally filled with planktonic and nectonic life, and the bottoms below are drilled with burrowing forms. Each animal or plant dying in such an area adds its calcareous test to the upbuilding of the bottom, and in so doing furnishes a point of attachment for its progeny and associates. Edgeward growth of the marine limestone banks is inhibited by upwelling cold currents, and organic deposition in the associated deeps is limited by the lack of light, heat, and food. The banks thus grow upward more rapidly than outward, and the original differences in elevation between the banks and deeps are gradually accentuated. Thus chemical and organic processes, acting together, produce submarine banks resembling mesas, with wide upper flats and steep edges. It is probable that the steepness of slope in these banks is due to an organic framework or reef on the margin which resisted the action of the waves.

The Yates pool occurs on the eastern edge of what seems to have been a shallow submarine limestone bank built up by normal sedimentary processes. This is shown by the presence of fossil casts, lithographic limestone, oölites, et cetera. Coral reefs have not been recognized in any of the wells on the Yates "high." This does not mean that reef material will never be found there. Corals are not necessary for the development of modern limestone banks and reefs, although, where missing, their place is ordinarily taken by other organisms. Between 1/3,000 and 1/6,000 of the area of the Bahama banks is occupied by living reefs. This proportion on the Yates "high" would occupy less than 1 square mile. The sharp steepening of the slope on top of the "brown lime" between the Mid-Kansas' Yates No. 27 and Yates No. 16 may be explained by the presence of an intervening reef or by a minor fault.

DEVELOPMENT OF POROSITY

On a broad shallow bank, there is a tendency for parts of the edges to build up slightly faster than the middle. This edge development is very noticeable around the Bahama banks, where all the islands occur on the margins of the deeps. It may be due to several causes. Among these are the greater food supply, causing denser accumulation of plants and animals; the breaking of the waves, causing aeration of the water and precipitation of limestone due to the loss of CO_2; and the rapid development of supersaturation in the cold waters passing over the edges of the warm shallow banks. These processes form a deposit somewhat similar to a natural levee. Edge ridges extending to the surface of the water will be built up into islands by the wind and waves,

and may, under favorable conditions, attain a considerable size. Andros Island, the largest island of the Bahamas, is about 100 miles long, and stands in places more than 100 feet above sea-level.

In regions where the edges of the banks are marked by growing structures, minor oscillations may alternately elevate and submerge the higher ridges. Vaughan[1] reports the occurrence of Pleistocene fossils above sea-level in the Bahamas, indicating elevation, and the presence of submerged solution potholes, not filled with sediments, showing that the last movement was downward. Davis[2] illustrates a series of two elevations and subsidences in volcanic islands surrounded by modern coral reefs, with elevated reefs, which grew in the deeply eroded valleys of the volcanic mountains. Many minor oscillations of this sort may have occurred during the development of some of the modern reefs and banks.

Islands developed from the shells, tests, and bones of marine animals, from the casts of lime-secreting algae, and from wind-blown calcareous sands, should be very porous. Commonly, on top of the banks between the islands, there is enough chemical and mechanical limestone mud or drewite to fill all the interstices between the larger fragments, and a dense lithographic limestone results. Only those parts of the bank which extend above the level of the sea as islands retain their original porosity. On the islands, however, not only is the original porosity retained, but it is probably increased by solution due to rain-water and the organic acids produced by vegetable decay. Alternating uplift and subsidence might produce porous island rock through a great thickness of strata, and the porous beds so produced might be continuous or separated by considerable thicknesses of non-porous rock. Field[3] drove a pipe into the calcareous sands of the Dry Tortugas and found that the shell sands of the key were especially porous for at least several feet below low-tide level and that the sea water passing through the island was affected by the rise and fall of the tide. Howard[4] believes that continuous porosity in limestones is developed by uplift above sea-level and exposure to leaching and erosion, and in no other way. It is probable that mechanical surface erosion on a porous limestone

[1] T. W. Vaughan, "Preliminary Remarks on the Geology of the Bahamas," *Carnegie Inst. of Washington Pub. 182* (1914), p. 54.

[2] W. M. Davis, "A Migrating Anticline in Fiji," *Amer. Jour. Sci.*, Vol. 14 (1927), pp. 333-52.

[3] R. M. Field, "Year Book," *Carnegie Inst. of Washington* (1919), p. 198.

[4] W. V. Howard, personal communication.

island would be reduced to a minimum and that solution would be the important erosive agent. Thomas[1] notes that the greater part of the rainfall sinks immediately into the ground and finds its way to the sea by underground passages. For this reason there are no streams of importance on the coral limestone parts of the island of Barbados. Similar conditions are reported from the limestone areas in Yucatan. Porosity of this type, to be preserved, must be submerged and buried before erosion and solution have had time completely to destroy it.

As already shown, limestone islands occur on the edges of the shallow limestone banks. Such islands possess porosity suitable for the natural reservoirs necessary in the accumulation of commercial quantities of oil. The position and shape of the porous part of the Yates pool, bordered as it is on three sides by a much more compact limestone probably deposited at a slightly lower level, suggest that the pool formed a marginal island on a limestone bank at the time of the development of the porosity. Further, commercial production is limited to that part of the bank which formed this island. With the present methods of gross correlation in use in West Texas, it is impossible to demonstrate unconformities within or above the "lime" in the Yates pool. It is probable, however, that not all of the porosity was developed during one period of exposure. The definite "pays," separated by fairly impervious limestones, suggest several recurrent elevations.

ORIGIN OF OIL

The problems that are encountered in explaining the origin of the oil in the Yates pool are not the same as those confronting geologists in most other Mid-Continent areas. In the Yates pool the limestone oils are not associated with bituminous shales or other common source rocks of petroleum. Howard[2] and others have found that oil can not migrate for long distances through limestone because of the high absorptive properties of the rock. This agrees in general with the data observed in West Texas, where there is no evidence of vertical migration. Therefore, it is necessary to look for the origin of the enormous amount of oil in the Yates pool in the immediate vicinity of the reservoir. The Yates pool is located on the edge of the pronounced basin underlying Crockett County, and it is suggested that the oil originated in this basin.

Benthonic accumulations of dead organisms are developing to-day on much of the ocean bottom. These deposits are prominent in the

[1] A. O. Thomas, personal communication.

[2] W. V. Howard, "Limestone and Dolomite as Reservoir Rocks," *Rept. Amer. Petrol. Inst. Project 23* (1929).

cold waters of some of the basins bordering the limestone banks in the sub-tropical seas. This slime or "soup" for which Agassiz[1] used the name "primordial pap" is formed from the bodies of the marine animals which inhabited the area. Swimming and floating forms, after dying, settle and are either eaten during transit or reach the bottom, where their remains are mixed with those of the sessile forms and other bottom dwellers. If they settle into the deeps or are quickly shifted off the banks, there is some chance of preservation. Otherwise, the remains are quickly devoured by the numerous scavengers, including such forms as echinoderms, crustaceans, gastropods, and worms.

The "benthonic soup" formed from this organic material is not concentrated unless differences in the topography of the ocean bottom are marked enough to protect the deposits from waves and currents. On the shallow level sea bottoms above the profile of equilibrium, the remains are continually shifted about until they become indistinguishable from the other sediments or until they have been carried beyond the continental shelf. This shifting and scattering process explains the origin of much of the disseminated bituminous matter encountered in limestones.[2] It probably explains the origin of the faint traces of oil which give a brownish color to part of the Permian limestone in West Texas. Even in basins the "soup" does not accumulate unless some effective check is placed upon the processes of decomposition and the activities of deep-water scavengers. This check can be rendered by refrigeration and the lack of light, or by the development of toxic conditions. To attain the proper refrigeration a temperature only slightly above freezing is required. This temperature in the Bahama Islands is reached at about 1,000 fathoms, but temperatures between 2° C. and −1.5° C. are encountered within 75 fathoms of the surface on the Newfoundland banks.[3] Due to this low temperature, however, no limestone is being deposited on the Newfoundland banks. It is not certain that, even in the deepest parts, the Permian basin maintained refrigerative bottom temperatures. In the absence of refrigeration, other preservative agents may have been effective. The depth of the Crockett County basin probably prevented circulation of the bottom waters which were below the zone of agitation. In these deeper stagnant waters, oxygen would be lacking, and toxins, formed by the life processes of organisms and from

[1] A. Agassiz, *Three Cruises of the U. S. Coast and Geodetic Steamer "Blake,"* Vol. 1 (Bull. Mus. of Comparative Zoöl., Harvard College, 1888), p. 203.

[2] F. W. Clark, "Data of Geochemistry," *U. S. Geol. Survey Bull. 770* (1924), p. 754.

[3] J. Murray and J. Hjort, *Depths of the Ocean* (Macmillan London, 1912), p. 110

the partial decomposition of the "soup," would accumulate. This condition would limit both bacterial action and further decay and effectively inhibit the activities of the larger scavengers. Preservation should also be aided by the concentration of brine, and this may have been an important factor in the deeper part of the Permian basin. It is quite evident, therefore, that the conditions favoring the accumulation of large deposits of organic material in the sea are those which are locally unfavorable for the existence of plant and animal life.

The "soup" becomes an important deposit in the limited area of the "soup bowls" only in the absence of excessive terrestrial or calcareous mud contaminations. It is most important in those areas where much of the limestone is formed by the life processes of organisms or in those "soup bowls" in which the bottom lies below the point at which limestone is dissolved. Chemically deposited limestone such as is forming on the Great Bahama Bank[1] would completely obscure any deposits which were formed, and if the calcareous muds thus produced settled into the "soup bowls" the basins would be quickly filled. The "soup" is preserved only if it is mixed with enough clastic material to form a framework and is sealed off by an impervious overlying bed. The "soup bowls" should be located in basins near an abundant source of life. Optimum conditions would be encountered in basins at the basal margin of a limestone bank. Such a basin would be ideal for the accumulation of thanatocoenose, which is Wasmund's[2] term for a product that differs very slightly from what is here termed "benthonic soup." Organic material of this type occurring in shale areas would produce bituminous shale or some of the other source rocks of petroleum. Trask[3] reports that the richest samples collected in his study of the origin and environment of the source rocks of petroleum came from basins in the sea floor. Some of these basins were in the Pacific Ocean west of Los Angeles and one was in the Gulf of Maine. These basins correspond with those already referred to as "soup bowls," although they are not in limestone-depositing areas and the "soup" has been mixed with considerable clastic material.

The deep basin east of the Yates pool offers an ideal "soup bowl" for the accumulation of organic material from which to generate petro-

[1] R. M. Field, "The Great Bahama Bank," *Amer. Jour. Sci.*, Vol. 1 (1928), pp. 239-46.

[2] E. Wasmund, *Biosociologische Studien über Lebengemeinschaften und Totengesellschafter Arch. Hydrobiol.*, Vol. 17 (1926), pp. 1-116.

[3] P. D. Trask, "Results of the Distillation and Some Other Studies on the Organic Nature of Modern Sediments," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11, No. 11 (November, 1927), pp. 1221-31.

leum. At the time of deposition of the upper "pure lime" on the field, there seems to have been a topographic difference ranging from 1,200 to 1,800 feet between the bottom of the Crockett County basin and the top of the Yates "high." This difference of 200 or 300 fathoms would have been enough to furnish the proper conditions for preservation. The fact that there was abundant life on the bank is shown by the number of fossils occurring in the cores taken from the upper part of the limestone. The deposits in the basin offer considerable evidence in themselves of being the source of the Yates oil. Many of them are dark-colored, and, when broken down with acid, contain many flakes of brown organic material. The area in which these dark sediments occur is extensive enough to have furnished all the oil in the Yates pool, even if the amount of the "benthonic soup" was no greater than it is in many parts of the present ocean.

The deposition of the upper part of the "Big lime" series in the Yates pool was accompanied by the deposition of considerable very fine gray sand. During this period, sandy limestone, of an average thickness of 100 feet, was deposited on the top of the structure. In the wells at the edge of the pool, the "sandy lime" zone is much thicker, and 3 miles farther east it is about 1,000 feet thick. The sand in this basin was probably supplied from the south or east. The small amount of limestone associated with the sand is interpreted as indicating rapid deposition or very deep water. It is probable that the oil migrating from the basin to the "high" traveled through sandstone rather than limestone. The sand production from the top of the limestone on the lower east edge of the pool suggests that such a channel existed.

FORMATION OF ANHYDRITE ROCK TRAP

Baker[1] has presented a possible hypothesis to explain the origin of the evaporites in the Permian basin. The anhydrite which forms the trap for the oil in the Yates pool is much denser than the associated magnesian limestones, and is noted for its lack of porosity in all parts of the basin. This is probably because it is a chemical precipitate throughout. The precipitation of the lower 100 feet or so of anhydrite on the east edge of the Yates pool was accompanied by the deposition of much fine sand. This was probably a continuation of the process commenced

[1] C. L. Baker, "Depositional History of the Red Beds and Saline Residues of the Texas Permian," *University of Texas Bur. Econ. Geol. Bull. 2901* (1929), pp. 9-73.

in the previous "sandy lime" period. The sand in this upper deposit seems to have been derived from the south and to have formed a sand bar along the edge of the field. In many places this "River bed" sand is porous enough to be an important producing horizon. For this reason, it was originally considered the equivalent of the upper part of the "lime" farther west. The presence of a thin tongue of magnesian limestone at the top of the sand further concealed the true relations. The prominent beds of anhydrite occurring here and there through the sandstone, the normalcy of the upper part of the limestone column below, and the characteristic distribution of the sand bar, are evidences that the "River bed" sandstone should be included with the evaporites, rather than with the "lime."

CONCLUSION

An attempt has been made to explain the origin of the reservoir and the oil in the Yates pool by recourse to processes operative in the modern seas. There is a marked steepening of the dip on top of the "lime" toward the northeast, and there is also a deep re-entrant on the southeast. The great thickening of the "sandy lime" series, the anhydrite below the Yates sand, and the upper salt show that the Yates area stood as a pronounced topographic "high" before "top of lime" time. The marked thinning of the limestone section toward the east strongly suggests that the Yates pool is on more of a depositional than a structural "high." Due to an initial difference in elevation, caused probably by folding, faulting, or erosion, deposition of limestone was practically limited to the higher side, which consequently was built up more rapidly than the lower, during a period of slow regional subsidence. The basin formed by this unequal deposition could easily have served as the "soup bowl" in which the mother liquid of petroleum was accumulated. The residual organic nature of the sediments in the basin further bears out this idea.

In the field, the porous reservoir occurs in the top of a pronounced limestone "high." Most of the cores or larger fragments of the rock that have been secured show the limestone of the porous horizons to be very fossiliferous. Occurring in a magnesian limestone, much of the porosity is due to the solution of the fossils after the solidification of the rock. The limited producing area is localized on a structure known to have been a topographic "high" at the time of deposition. This suggests that the pool represents a buried limestone "high" which formed an island at

the time of the development of the proosity, and that the oil migrated into this porous island reservoir after the deposition of the anhydrite which serves as an impervious trap.

DEEP SAND DEVELOPMENT AT BARBERS HILL, CHAMBERS COUNTY, TEXAS[1]

P. C. MURPHY[2] and SIDNEY A. JUDSON[3]
Houston, Texas

ABSTRACT

The writers describe the development of this dome since 1924, which is the final date of the original article on this field by George Bevier.

Barbers Hill is a large shallow salt dome located in the Texas Gulf Coastal Plain in the general vicinity of other productive salt domes.

Oligocene sands have yielded wells of the gusher type from a 5,100-foot sand horizon for the past 15 months, after years of unprofitable exploration of shallower sands. A 10,000-barrel well from a depth of 6,416 feet on an undeveloped flank of the dome in a deeper horizon in a formation probably of Oligocene age indicates a new stratum, richer than those already found. Seventy-one deep producing wells have been drilled during this recent period. The total production for 1929 was 4,487,000 barrels.

An exceptional condition is found on the northeast flank of the dome, where several hundred feet of cap rock and salt between the depths of 1,500 and 2,500 feet jut out from the main intrusive mass. Many wells have drilled through this and have found the sedimentary beds below, including oil sands, practically undisturbed by this overhanging mass.

The general characteristics of the dome and flank formations are indicated by several cross sections.

A map of the field shows the approximate inside limit of production. Production records and well histories are shown by graphs and tables.

ACKNOWLEDGMENTS

The writers are indebted to nearly every operator at Barbers Hill for data received. This information was of great aid in the preparation of the article. Laboratories of the Humble Oil and Refining Company and of The Pure Oil Company furnished many of the paleontological data.

INTRODUCTION

Barbers Hill salt dome is in the northwest part of Chambers County, Texas, about 27 miles east of Houston. Its position with relation to the near-by oil fields of South Liberty, Moss Bluff, Lost Lake, Goose Creek, Esperson, and Humble is shown in Figure 1. This map also gives the

[1]Read before the Association at the New Orleans meeting, March 20, 1930. Manuscript received by the editor, February 19, 1930.

[2]Assistant to the president, Humphreys Corporation.

[3]Chief geologist, Humphreys Corporation.

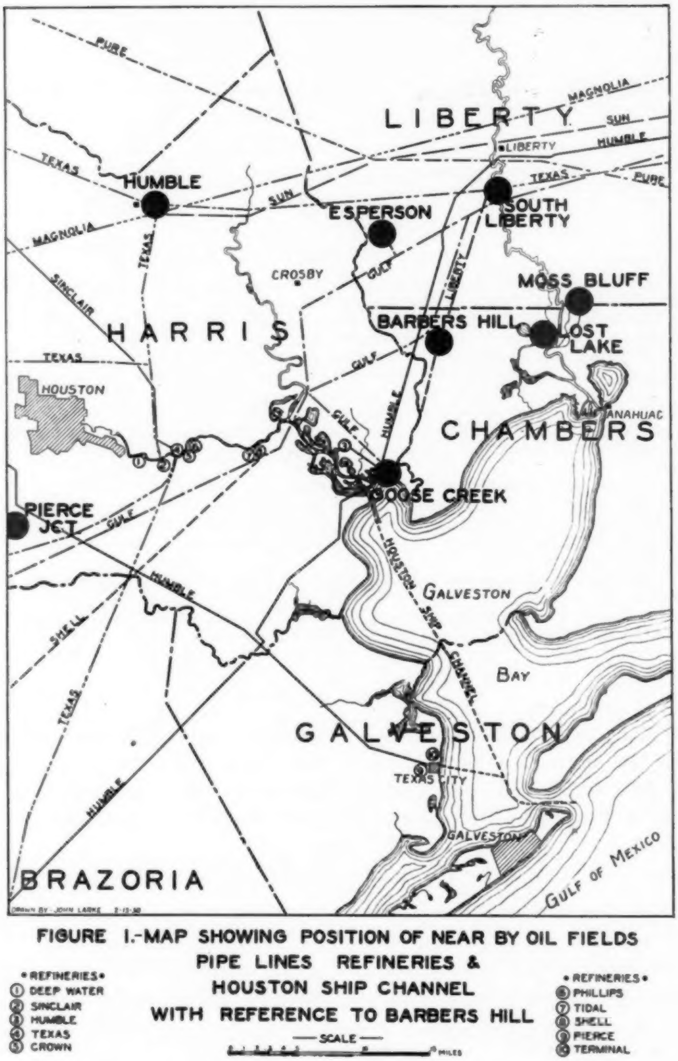


FIG. 1.—Map showing position of near-by oil fields and Houston ship channel with reference to Barbers Hill.

relation of the dome to the Houston ship channel and the various near-by pipe lines and refineries.

Topographically, the dome consists of a hill, oval in shape, rising 45 feet above the surrounding coastal plain.

HISTORY OF DEVELOPMENT

The early history of this field, up to August, 1924, has been fully described by George Bevier[1] in his article on Barbers Hill. Up to that time one hundred and twenty tests had been drilled, of which twenty-six were producers. Ten of these were shallow tests for sulphur. The development included by the present writers begins at the end of the period covered by Bevier. Development, with possibly a single exception, had not penetrated deeper than the Miocene formation, in which a comparatively small production had been obtained on the southwest flank, amounting to a total of only 780,524 barrels.

On account oi these discouraging results, there was no further development of the dome until 1926, when the Mills Bennett Production Company drilled five additional wells on the southwest flank, adjoining previous producing wells. At nearly the same time, the Mills Bennett Production Company and the Humphreys Corporation, drilling jointly, obtained oil on the northwest flank of the dome in the upper Miocene or lower Pliocene sands. The discovery well, their A. E. Barber No. 1, had an initial flow of 500 barrels of 32° gravity oil. The location of wells is found on a base map of the dome in Figure 2.

Within a small area thirteen wells were drilled to this horizon, six of which were producers. The seeming lenticularity of the sand retarded further development. Two tests were carried below 3,200 feet, but these developed no deeper production, although showings of oil were obtained.

A few months later, in November, 1926, the Mills Bennett Production Company and the Humphreys Corporation, again drilling jointly, found a better Miocene sand on the northeast flank of the dome. The discovery well, Kirby B-2, flowed 800 barrels of 25° gravity oil from sands ranging from 4,091 feet to 4,174 feet in depth. Two additional producers, Kirby B-3 and B-4, were obtained offsetting this well. The Humphreys Corporation's Kirby B-5 was drilled 150 feet closer to the dome in an effort to find these sands higher. This well drilled the cap rock from 2,193 to 2,223 feet and lost returns in a cavity just below

[1]George Bevier, "Barbers Hill Salt Dome," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 6 (September, 1925), p. 958.

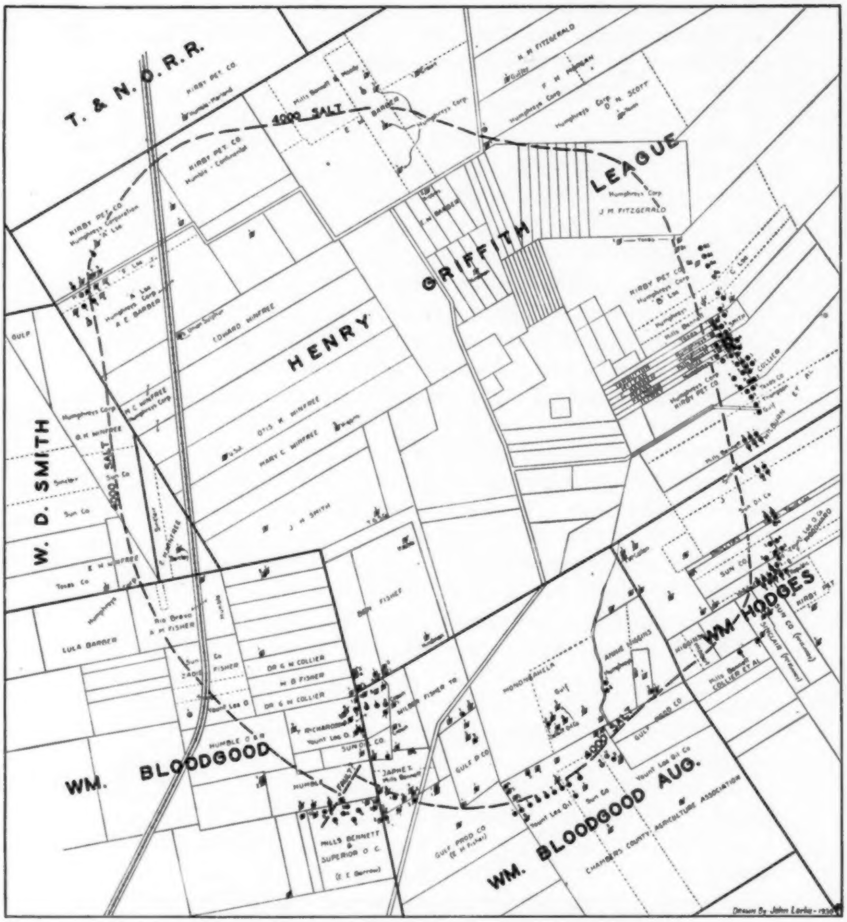


FIGURE 2.—BARBERS HILL SALT DOME
CHAMBERS CO., TEXAS
SHOWS APPROXIMATE 4000 FOOT CONTOUR ON SALT
SCALE IN FEET

FIG. 2

it. This well, however, was drilled deeper and went back into sedimentary beds and continued through a section of alternating gumbo, shale, and sands to a depth of 4,950 feet, where the hole was junked. This well reached the *Discorbis* zone of the Oligocene at a depth of 4,804 feet. This was the first well at the dome to find thick sedimentary beds under the cap rock. The Mills Bennett Production Company's Kirby No. 1, 500 feet farther south along the dome, missed the 4,100-foot Miocene sand horizon and tested salt water in a partly saturated sand from 4,953 to 4,995 feet in the *Discorbis* zone of the Oligocene. This well was drilled to the *Heterostegina* zone of the Oligocene and completed at a total depth of 5,468 feet, making a 200-barrel producer. The well, however, flowed pipe-line oil for a few hours at the rate of 1,200 barrels per day before water broke in from an upper sand. This was the discovery well of the prolific horizon now producing on the east and south flanks. This led to the drilling of the Mills Bennett Production Company's Smith No. 1, 325 feet south, which was completed on October 9, 1928, with an initial flow of 4,000 barrels of 27° gravity oil from a depth of 5,240-5,278 feet and which definitely established a sand of gusher type on this dome. The area adjacent on the south is divided into small tracts and was drilled up without delay. Thirty-six wells were drilled in an area 1,600 feet long and 200-300 feet wide. Most of these were completed as good flowing wells.

In the mean time, on January 29, 1929, the Yount Lee Oil Company completed their Chambers County Agricultural Association No. 1 with an initial flow of 4,700 barrels from sands ranging from 5,107 to 5,318 feet in depth. This well is on the south flank of the dome and is producing from the same zone as the wells on the east flank. A narrow line of flowing wells along the dome was obtained in this area. The Yount Lee Oil Company's Chambers County Agricultural Association No. 4, which was completed as a dry hole at a total depth of 8,148 feet, is the deepest hole in the Gulf Coast district.

An area midway between these two groups of wells was opened by the Republic Production Company's Kirby No. 1, completed on July 27, 1929, with 3,420 barrels of initial production from a total depth of 5,194 feet from the same horizon of the Oligocene as the two earlier areas already mentioned. Encouraged by the success obtained in the two former deep sand areas, different operators quickly commenced several wells in the vicinity of this well. Most of these were completed as flowing producers, although the size of the first producing wells was somewhat more erratic than in the two other areas. Up to the present,

seventy-one producing wells and six dry holes have been drilled in the deep sands on these flanks of the dome.

The Humphreys Corporation's Kirby A-8, located on the northwest flank close to several small shallow wells and dry holes, and more than 2 miles around the dome from the nearest deep production, was brought in, January 4, 1930, with an initial flow of 10,262 barrels per day of 34° gravity oil. The oil comes from sand between 6,397 feet and 6,416 feet in depth, probably in the non-fossil zone of the lower Oligocene, although positive paleontological evidence has not been found. It is the deepest producer in the Gulf Coast district of Texas, although two deeper producers have been obtained in the Gulf Coast district of Louisiana at the Jennings salt dome.

SUBSURFACE GEOLOGY

The intrusion of the salt plug through the surrounding formations is shown on the northwest-southeast cross section in Figure 3, with its relation to the uplifts at Humble, Esperson, and Lost Lake domes.

Humble and Barbers Hill are alike in that the salt in these domes has pushed its way up close to the surface through the Miocene and Oligocene, and the oil in these two formations has collected in the sands against the sides of these domes. Humble, in contrast to Barbers Hill, has produced much cap-rock oil. The intrusive mass at Lost Lake and Esperson, however, is much farther below the surface, and the oil produced up to the present has been found only in the formations above the dome. The flanks of these two domes have not yet been explored sufficiently to determine whether or not oil is present.

The general characteristics of the dome at Barbers Hill, as well as its relation to the surrounding sediments, are indicated in sections across the dome, shown in Figures 5, 6, and 7. Figure 4 is a key map showing location of the cross sections.

The salt plug at Barbers Hill is oval in outline and is covered with thick successive layers of anhydrite, gypsum, and secondary limestone, typical of the average coastal salt dome. The sides of the intrusive mass seem to be either approximately vertical, or with a slight inverted cone effect below 3,000 feet, except on the southwest flank, where salt was found in the Mills Bennett Production Company's Japhet No. 4 at a depth of 4,060 feet. This is the only flank well on the dome that has reached salt below 4,000 feet. The opposite flank of the dome, however, indicates that there the shallow cap and salt protrude out beyond the deeper salt body and form what is locally known as an "overhang."

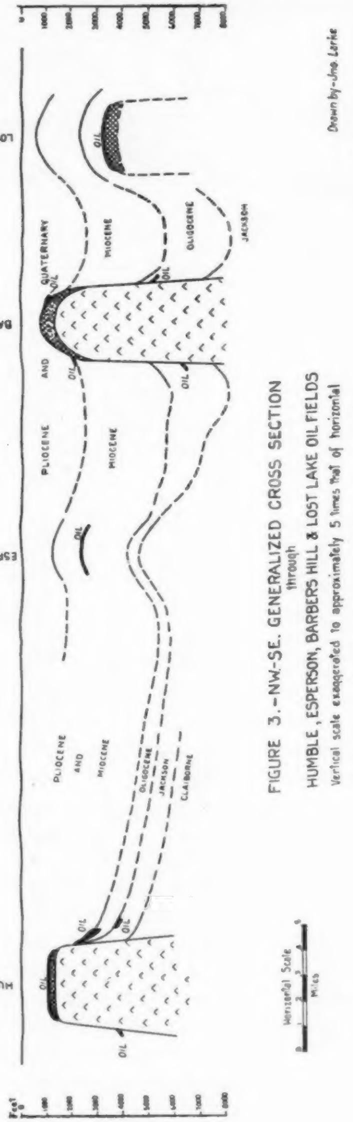


FIGURE 3.-NW-SE. GENERALIZED CROSS SECTION
through
HUMBLE, ESPERSON, BARBERS HILL & LOST LAKE OIL FIELDS
Vertical scale exaggerated to approximately 5 times that of horizontal

FIG. 3

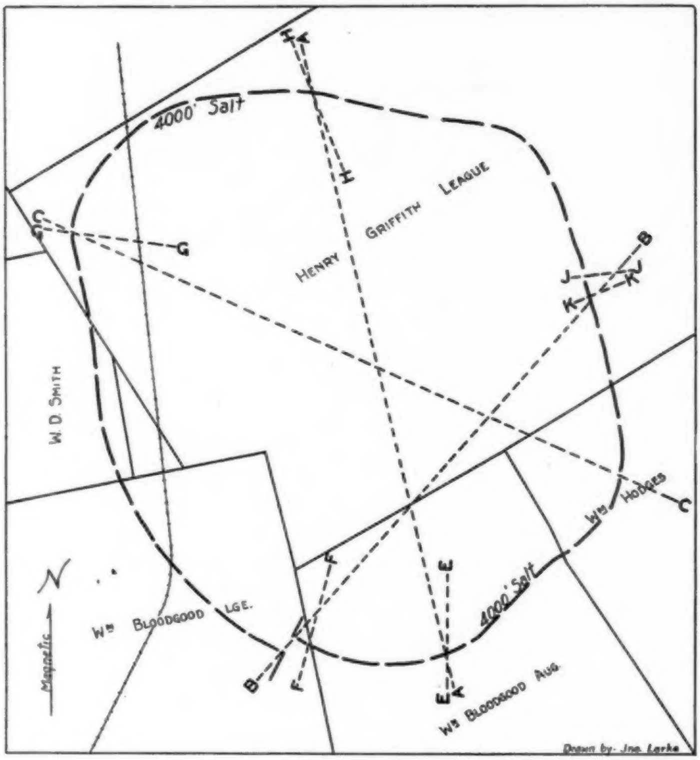


FIGURE 4
KEY MAP SHOWING LOCATIONS OF CROSS SECTIONS
BARBERS HILL SALT DOME
SCALE

FIG. 4

This condition is illustrated by the Humphreys Corporation's Ilfrey No. 2 in Section *B-B,* Figure 6. The other two cross sections, *A-A* in Figure 5 and *C-C* in Figure 7, illustrate the more general shape of the dome in which the sides below 3,000 feet are shown nearly vertical or slightly overhanging. Inasmuch as only one well has reached salt below 4,000 feet, insufficient data are available to determine whether the

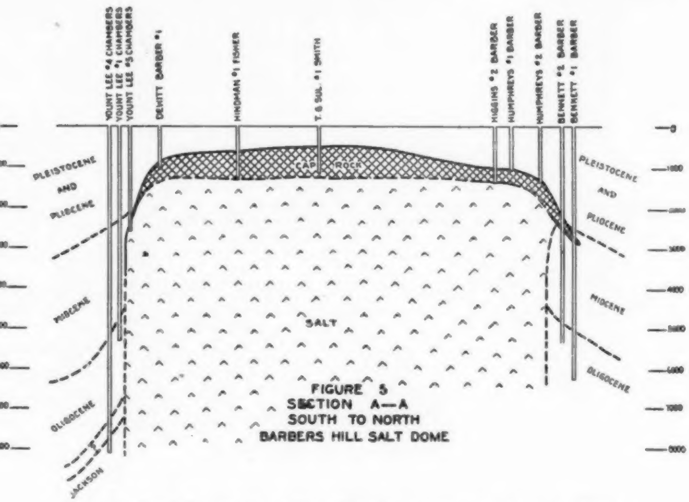


FIG. 5.—(Depths in this and the following figures are shown in feet.)

deeper salt is practically vertical or whether a considerable overhang exists. Additional details of the shape of the salt and cap on the several flanks of the dome are illustrated in Figure 8. Sections *H-H*, *J-J*, and *K-K* of Figure 8 show exceptional examples of overhanging cap or salt which occur on the north and east. This dome is one of the few in which deep oil sands have been regularly found beneath protruding cap or salt. At least sixteen wells on the east and north flanks have drilled through overhanging cap rock and four wells have drilled through overhanging salt under the cap rock. All of these wells went back into sedimentary formations immediately below the overhang, and the formations below were not noticeably affected by the overhanging cap and salt. The Humphreys Corporation's Ilfrey No. 2 drilled through 878 feet of salt between 1,531 and 2,499 feet and is now drilling in sedimentary formations at 4,281 feet. These facts lead to the conclusion that on this dome, at least, wells which reach salt near a known steep flank should penetrate it 1,000 feet or more before being abandoned. It is believed that this practice could well be extended to other domes with steep flanks, for few domes of this type have had the edges of the cap rock and salt sufficiently explored to determine whether or not an overhang exists.

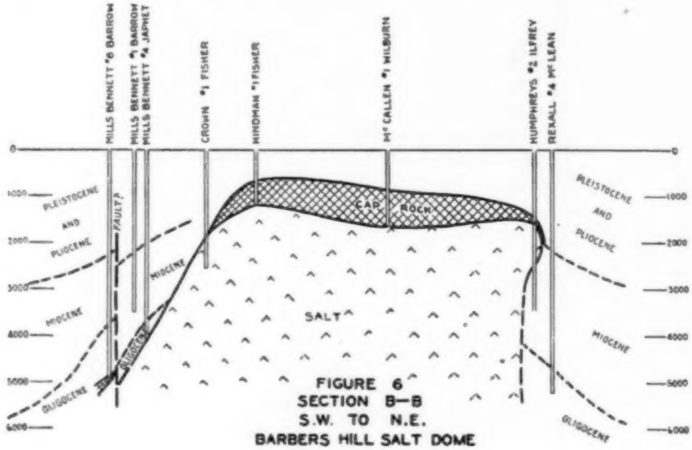

MILLS BENNETT #6 BARROW
MILLS BENNETT #1 BARROW
MILLS BENNETT #4 JAPHET
CROWN #1 FISHER
HINDMAN #1 FISHER
McCALLEN #1 WILBURN
HUMPHREYS #2 ILFREY
REXALL #4 McLEAN
0
1000
2000
3000
4000
5000
6000
PLEISTOCENE
AND
PLIOCENE
MIOCENE
OLIGOCENE
FAULT?
CAP ROCK
SALT
FIGURE 6
SECTION B—B
S.W. TO N.E.
BARBERS HILL SALT DOME

FIG. 6

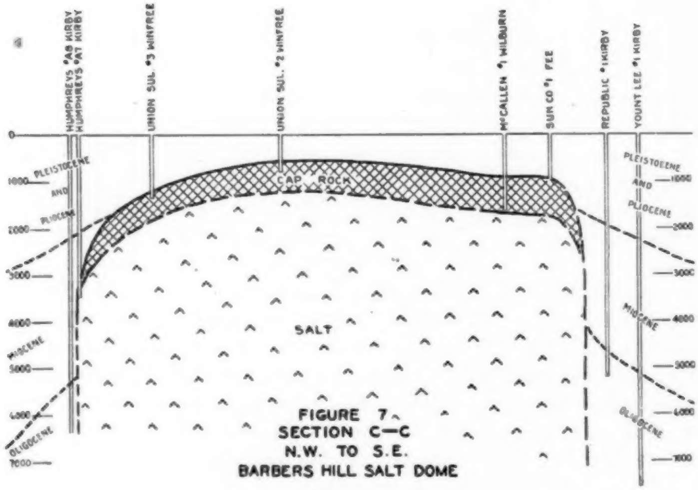

HUMPHREYS #A8 KIRBY
HUMPHREYS #A7 KIRBY
UNION SUL. #3 WINFREE
UNION SUL. #2 WINFREE
McCALLEN #1 WILBURN
SUN CO #1 FEE
REPUBLIC #1 KIRBY
YOUNT LEE #1 KIRBY
0
1000
2000
3000
4000
5000
6000
7000
PLEISTOCENE
AND
PLIOCENE
MIOCENE
OLIGOCENE
CAP ROCK
SALT
FIGURE 7
SECTION C—C
N.W. TO S.E.
BARBERS HILL SALT DOME

FIG. 7

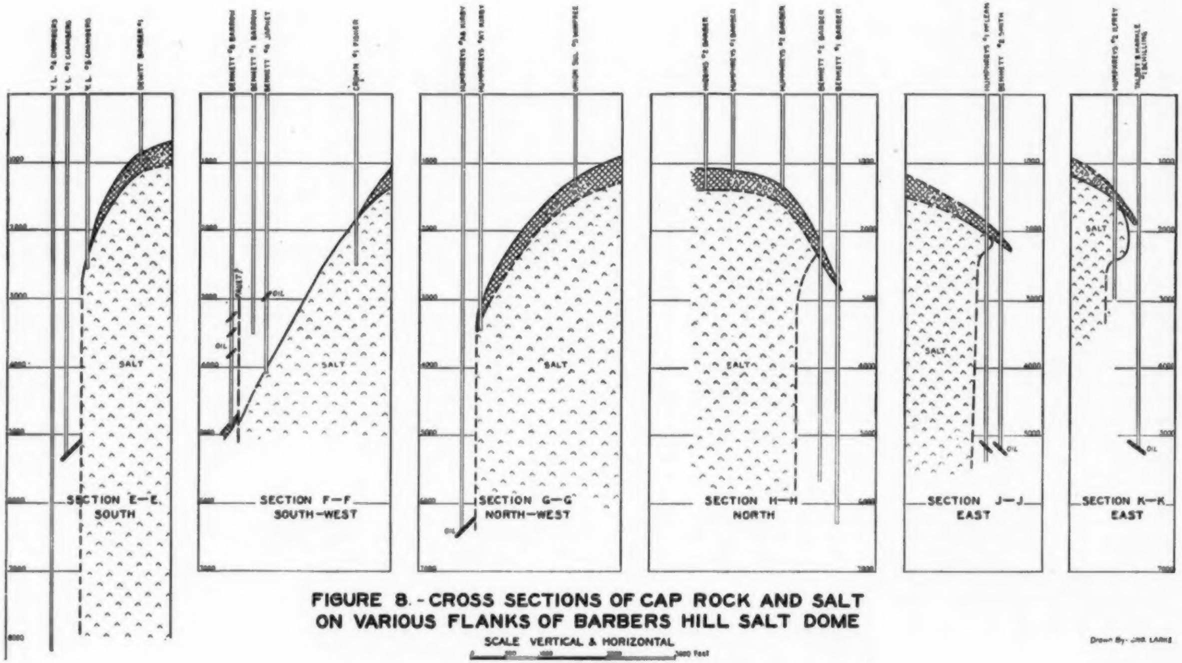


FIGURE 8. - CROSS SECTIONS OF CAP ROCK AND SALT ON VARIOUS FLANKS OF BARBERS HILL SALT DOME

SCALE VERTICAL & HORIZONTAL

Drawn By - JNO. LARKE

Fig. 8

Sections *E-E*, *F-F*, and *G-G* of Figure 8 illustrate nearly vertical or outward sloping salt on the west and south flanks.

The character of the anhydrite, gypsum, and limestone cap rock is described by Bevier.[1] The especially thick cap rock of the dome and the nearly vertical flanks make possible accurate interpretation of torsion-balance surveys in locating the position of the outside limits of the intrusion, although the amount of overhang of the salt body can not be determined by these methods.

STRATIGRAPHY

The columnar section in Figure 9 shows the stratigraphy as found in a typical producing flank well close to the dome. The sediments penetrated by the drill are successively of Pleistocene, Pliocene, Miocene, Oligocene, and Eocene age. The Pleistocene, Pliocene, and Miocene have been described by Bevier[2] and by Applin, Ellisor, and Kniker.[3] The Oligocene and the Jackson formation of Eocene age are generally similar in character to these formations on near-by domes as described by the last three writers. The contact between the Oligocene and Jackson is not yet fully determined by paleontological evidence, but the two probably limiting positions are shown in the columnar section in Figure 9.

It is of special interest to notice the various incursions of lignitic shale into the basal Oligocene, which cause this to be easily mistaken for the Jackson formation. If the contact between the Oligocene and Jackson formations is assumed to be approximately 400 feet above the *Textularia hockleyensis* zone in the Yount Lee Oil Company's Chambers County Agricultural Association No. 4, the total thickness of the Oligocene formation must be about 2,100 feet. This amount is exceptionally great for the Oligocene, if compared with its thickness found either on near-by domes, or on those slightly farther inland, which are the domes in which the Oligocene has already been explored. This formation shows many sand bodies, alternating with shales and gumbos on all flanks of the dome.

STRUCTURE OF SURROUNDING SEDIMENTS

The dip of the surrounding sediments as they slope away from the dome is indicated in Figures 5, 6, and 7. The wells shown in these sec-

[1] *Op. cit.*

[2] *Op. cit.*

[3] Esther Richards Applin, Alva C. Ellisor, and Hedwig T. Kniker, "Subsurface Stratigraphy of the Coastal Plain of Texas and Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 1 (January-February, 1925), pp. 79-122.

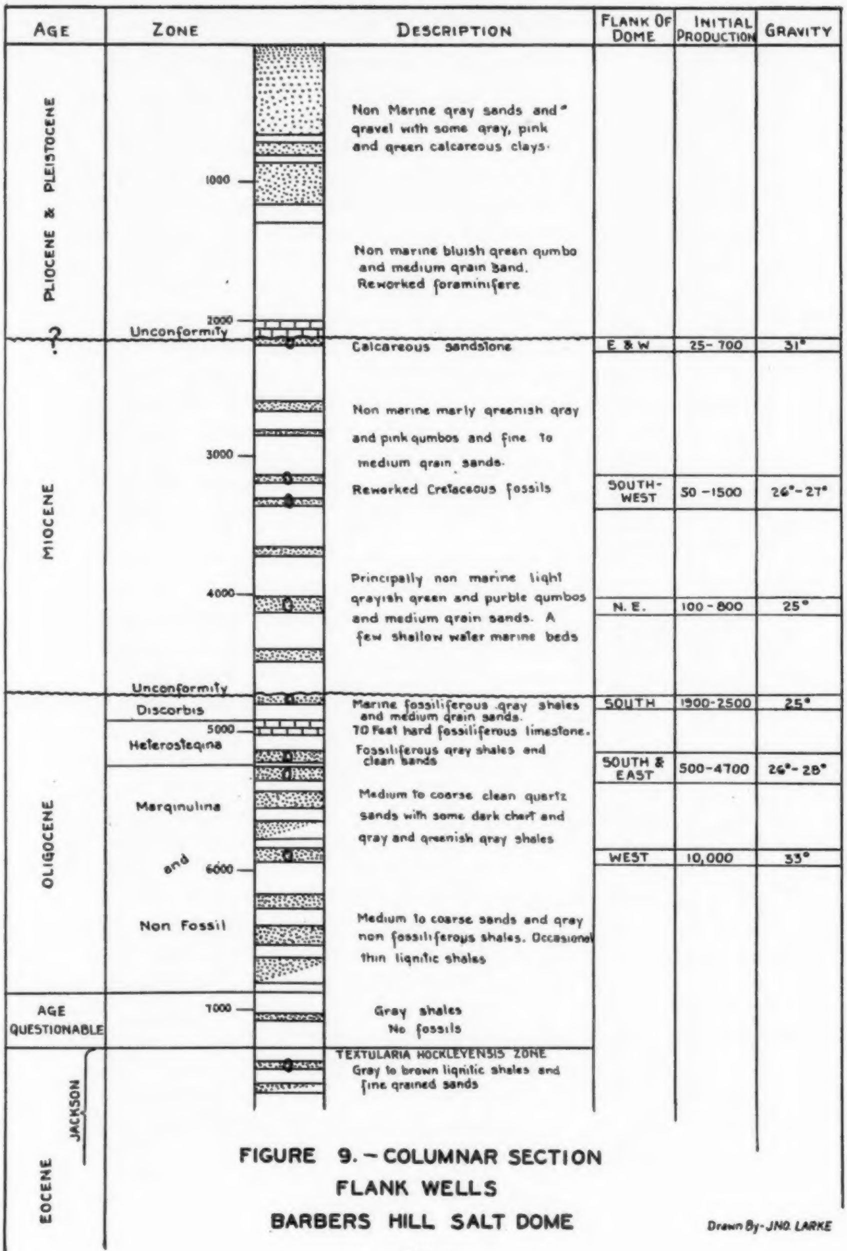

AGE
ZONE
DESCRIPTION
FLANK OF DOME
INITIAL PRODUCTION
GRAVITY
PLIOCENE & PLEISTOCENE
Non Marine gray sands and gravel with some gray, pink and green calcareous clays.
1000
Non marine bluish green gumbo and medium grain sand. Reworked foraminifere
2000
?
Unconformity
Calcareous sandstone
E & W
25 - 700
31°
MIOCENE
Non marine marly greenish gray and pink gumbos and fine to medium grain sands.
3000
Reworked Cretaceous fossils
SOUTH-WEST
50 - 1500
26°-27°
Principally non marine light grayish green and purble gumbos and medium grain sands. A few shallow water marine beds
4000
N. E.
100 - 800
25°
Unconformity
OLIGOCENE
Discorbis
Marine fossiliferous gray shales and medium grain sands.
SOUTH
1900-2500
25°
5000
Heterostegina
70 Feet hard fossiliferous limestone.
Fossiliferous gray shales and clean sands
SOUTH & EAST
500-4700
26°-28°
Marginulina
Medium to coarse clean quartz sands with some dark chert and gray and greenish gray shales
WEST
10,000
33°
and
6000
Non Fossil
Medium to coarse sands and gray non fossiliferous shales. Occasional thin lignitic shales
AGE QUESTIONABLE
7000
Gray shales
No fossils
EOCENE
JACKSON
TEXTULARIA HOCKLEYENSIS ZONE
Gray to brown lignitic shales and fine grained sands
FIGURE 9. - COLUMNAR SECTION
FLANK WELLS
BARBERS HILL SALT DOME
Drawn By - JNO. LARKE

FIG. 9

tions are assumed for this purpose to be straight. However, the surveys of at least twenty-five wells have proved that the average deep well deviates considerably from the vertical. Accordingly, sections based upon correlations between wells on known horizons, such as the *Heterostegina* limestone, would be highly inaccurate in regard to dip where the deep wells are only a few hundred feet apart, as they are in most of the sections used. As only a few of the surveys mentioned show the direction as well as the deviation of the hole, it is not possible, without additional surveys, to know the exact dip of the horizons. Dips are found in cores of shale and sandy shales, varying from about 25° in the Oligocene on the northeast flank to about 45° in the same formation on the northwest flank. It is questionable whether these dips represent actual dips of the horizons, but they probably approximate them. It is not definitely known whether or not much faulting exists in the sediments on the flanks of the dome, although considerable local faulting seems to be present on the southwest flank in the vicinity of the Mills Bennett Production Company's Barrow No. 8. Many supposed local faults are easily explained by crooked holes.

DRILLING METHODS

Drilling practice in this field compares favorably with the methods used in the principal deep rotary fields of the Mid-Continent region and California. Special methods have been developed to take care of the particular problems that naturally occur around an intrusion of salt and porous cap rock surrounded by unconsolidated sands, shales, and a few hard beds of calcareous sandstone. Wells in the 5,100-foot sand are completed in an average time of 55 days and ordinarily require only one string of casing besides the surface string. The producing string is cemented in gumbo directly above the oil sand, and liner and screen of proper mesh are then set in the sand and sealed off 100 feet or so above the bottom of the casing.

Where production is expected, sand sections are thoroughly cored. Core barrels which drill the full size of the hole and take cores with a maximum length of 20 feet save considerable time. Surveys to determine deviation from the vertical have been run in about 30 per cent of the wells, and surveys which show direction as well as amount of deviation have been made in about 10 per cent of the wells. When a hole is found to be very crooked it can ordinarily be corrected by redrilling a part of it. Surveys greatly aid the geologist in considering the problems of new locations and proper drainage of the sand body.

Determinations of formations and their zones are made principally by paleontological examination. However, the *Heterostegina* limestone of the Oligocene formation, consisting of 70 feet of hard fossiliferous limestone, and located 150-200 feet above the 5,100-foot pay zone, provides the operator with an accurate drilling marker. Subdivision of the sand bodies into their individual beds is aided by comparison of washed samples of the sands, which ordinarily possess noticeably different characteristics which make possible close correlations for short distances. Quantitative determinations of salt and oil content, combined with the observed gaseous odor, help in deciding whether or not to set screen in a particular sand. Experience has shown that a sand which will produce oil can not ordinarily be distinguished by any of the tests mentioned, but rather by a combination of all three.

OIL AND GAS

The total production for the year 1929 was 4,487,000 barrels. Nearly all of this was produced from the Oligocene sands in the three separate areas on the south, southeast, and east flanks previously mentioned. These three areas are all highly productive in the 5,100-foot zone, although the most northerly of these areas has been developed more intensively and has produced more oil than either of the others. The flank leases between these three areas are being gradually drilled up, following common Gulf Coast practice. The combined length of these three productive areas is 9,500 feet and is considered proved for the 5,100-foot zone. The width of the producing zone ranges from one location on the south to 400 feet on the southeast and east flanks. It has not yet been defined along the dome in either direction by dry holes, and in only a few places by salt wells on the side toward the dome. The probable inner boundary of production is indicated in Figure 2 by the approximate 4,000-foot salt contour shown on that map. As only one flank well on the entire dome has reached the salt as low as 4,000 feet, it is realized that the contour used is only hypothetical. Small wells or dry holes have been obtained on the side away from the dome, defining the edge of production of the zone in that direction.

The initial daily production ranges from 600 to 4,700 barrels with the initial production of the average well varying from 1,000 to 2,000 barrels. The flowing life of these wells varies greatly according to spacing, drainage, manner of completion, and method of flowing. The average well, however, will return the investment cost during its flowing period. Several of the best wells have produced to date more

TABLE I

Development at Barbers Hill
(September 1, 1924—January 31, 1930)

C = Cap rock   S = Salt   H. L. = *Heterostegina* limestone

Operator	*Tract*	*Well Number*	*Date Completed*	*Barrels Initial Production*	*Feet Total Depth*	*Remarks (Figures in Feet)*
M. Bennett Prod. Co.	Barrow, E. E.	3	4–12–26	200	3,070	
M. Bennett Prod. Co.	Barrow, E. E.	4	6–19–26	400	3,212	
Bennett-Moody	Barrow, E. E.	5	3–17–27	800	4,551	
Bennett-Moody	Barrow, E. E.	6	1–25–27	Dry	5,055	
Bennett-Moody	Barrow, E. E.	7	5–13–27	300	3,900	
Bennett-Moody	Barrow, E. E.	8	8– 8–27	200	3,356	C 4,803-4,868
Bennett-Moody	Barrow, E. E.	9	10– 6–27	600	3,212	
M. Bennett Prod. Co.	Collier	1	12– 5–29	10	5,490	H. L. 4,937-4,966
M. Bennett Prod. Co.	Collier	2	1– 9–30	890	5,408	
M. Bennett Prod. Co.	Hamman	1	6– 1–29	1,500	5,195	H. L. 4,840-4,897
M. Bennett Prod. Co.	Hamman	2	7–24–29	3,500	5,143	H. L. 4,790-4,837
M. Bennett Prod. Co.	Hamman	3	12– 1–29	50	5,166	H. L. 4,852-4,903
M. Bennett Prod. Co.	Japhet	4	3– 4–26	Dry	4,070	S 4,060-4,070
M. Bennett Prod. Co.	Japhet	6	–26	Dry		
M. Bennett Prod. Co.	Japhet	7	4–24–26	Dry	2,950	
M. Bennett Prod. Co.	Japhet	8	5– 7–27	Dry	3,007	
M. Bennett Prod. Co.	Barber, E. W.	1	10–12–29	Dry	6,282	C 2,440-2,565 H. L. 5,263-5,332
M. Bennett Prod. Co.	Kirby Pet. Co.	1	11–20–27	1,200	5,468	H. L. 5,129-5,146 Oligocene sand discovery well on E. flank
M. Bennett Prod. Co.	Kirby Pet. Co.	2	4– 8–29	380	5,397	H. L. 5,095-5,163
M. Bennett Prod. Co.	Means, J. B.	1	4– 6–29	1,850	5,255	H. L. 4,922-4,995
M. Bennett Prod. Co.	Means, J. B.	2	1–31–30	1,900	5,137	H. L. 4,930-4,963
M. Bennett Prod. Co.	Smith	1	10– 9–28	4,000	5,272	H. L. 4,973-5,041
M. Bennett Prod. Co.	Smith	2	5–22–29	1,400	5,197	H. L. 5,059-5,119
M. Bennett Prod. Co.	Smith	4	12–12–29	2,600	5,357	
M. Bennett Prod. Co.	Wilburn	1	12–12–29	600	5,194	H. L. 4,783-4,845
M. Bennett Prod. Co.	Wilburn	2	1–23–30	1,565	5,159	H. L. 4,810-4,869
Barclay & Meadows	Barber, A. E.	1	–26	150	2,204	
Barclay & Meadows	Barber, A. E.	2	–26	150	2,239	
Barclay & Meadows	Barber, A. E.	3	–26	Dry	2,000	
Joe Bashara	Tarbutton	1	4–22–29	750	5,236	C 2,112-2,257 H. L. 4,927-5,006
Bennett-Humphreys	Barber, A. E.	1	5–14–26	500	2,245	Discovery well on NW. flank
Bennett-Humphreys	Barber, A. E.	2	8– 1–26	Dry	3,488	
Bennett-Humphreys	Barber, A. E.	3	8–15–26	150	2,230	
Bennett-Humphreys	Barber, A. E.	4	9–22–26	Dry	2,459	
Bennett-Humphreys	Barber, A. E.	5	12–19–26	Dry	3,215	
Bennett-Humphreys	Kirby Pet. Co.	1-A	3–10–26	Dry	1,582	
Bennett-Humphreys	Kirby Pet. Co.	2-A	8– 7–26	Dry	3,137	
Bennett-Humphreys	Kirby Pet. Co.	3-A	9–23–26	530	2,205	
Bennett-Humphreys	Kirby Pet. Co.	4-A	10–12–26	Dry	2,546	
Bennett-Humphreys	Kirby Pet. Co.	5-A	2– 1–27	100	2,251	
Bennett-Humphreys	Kirby Pet. Co.	1-B	8–23–26	Dry	1,789	C 1,785-1,789
Bennett-Humphreys	Kirby Pet. Co.	2-B	11– 7–26	300	4,118	Discovery well on NE. flank

TABLE I—*Continued*

Operator	*Tract*	*Well Number*	*Date Completed*	*Barrels Initial Production*	*Feet Total Depth*	*Remarks (Figures in Feet)*
Bennett-Humphreys	Kirby Pet. Co.	3-B	1–19–27	800	4,425	
Gulf Prod. Co.	Fisher Fee	1	5–18–29	1,000	5,590	H. L. 5,087-5,148
Gulf Prod. Co.	Wilburn	1	12–10–29	450	5,216	H. L. 4,883-4,949
Hindman, S. J.	Bullock	1	4–25–25	Dry	3,330	
Humble O. & R. Co.	Kirby Pet. Co.	1	–27	Dry	5,789	H. L. 5,485-5,542
Humphreys Corp.	Barber, E. W.	1-A	5– 6–28	Dry	1,151	C 1,147-1,151
Humphreys Corp.	Barber, E. W.	2-A	8–17–28	Dry	1,358	C 1,343-1,358
Humphreys Corp.	Barber, E. W.	3-A	12–16–28	Dry	2,606	
Humphreys Corp.	Barber, C.	1	3– 5–29	2,300	5,194	C 2,140-2,216 H. L. 5,042-5,115
Humphreys Corp.	Ilfrey	1	8–16–29	1,650	5,165	C 2,029-2,242 H. L. 4,842-4,874
Humphreys Corp.	Kirby Pet. Co.	6-A	12–13–27	Dry	2,397	
Humphreys Corp.	Kirby Pet. Co.	7-A	5– 4–29	Dry	3,464	C 2,925-3,259 S 3,259-3,460
Humphreys Corp.	Kirby Pet. Co.	8-A	1– 4–30	10,262	6,416	H. L. 5,408-5,510
Humphreys Corp.	Kirby Pet. Co.	4-B	6–27–27	100	4,150	
Humphreys Corp.	Kirby Pet. Co.	5-B	10–27–27	Dry	4,949	
Humphreys Corp.	Kirby Pet. Co.	1-C	1– 3–29	2,500	5,223	H. L. 4,922-4,997
Humphreys Corp.	Kirby Pet. Co.	1-H	8–23–29	1,700	5,071	C 2,135-2,186 H. L. 4,754-4,843
Humphreys Corp.	Kirby Pet. Co.	2-H	8–16–29	2,300	5,248	H. L. 4,865-4,935
Humphreys Corp.	Kirby Pet. Co.	3-H	8–27–29	1,875	5,202	H. L. 4,809-4,873
Humphreys Corp.	Kirby Pet. Co.	4-H	10–11–29	1,800	5,123	H. L. 4,723-4,777
Humphreys Corp.	Kirby Pet. Co.	5-H	10–17–29	1,200	5,130	H. L. 4,760-4,812
Humphreys Corp.	Kirby Pet. Co.	6-H	10–28–29	1,736	5,108	C 2,095-2,165 H. L. 4,705-4,756
Humphreys Corp.	Kirby Pet. Co.	7-H	11–14–29	720	5,055	C 2,087-2,167
Humphreys Corp.	Higgins	1	12– 4–28	25	857	C 815-857
Humphreys Corp.	Higgins	2	10–16–29	15	841	C 821-841
Humphreys Corp.	Scott	1	12–14–29	Dry	2,906	C 1,626-1,889 S 1,889-1,927 C 1,927-1,979 S 1,979-1,991 C 1,991-2,019 S 2,019-2,906
Humphreys Corp.	Tarbutton	1	8–28–29	1,600	5,224	C 2,081-2,263 H. L. 4,955-5,038
Humphreys Corp.	Wilburn	1	9–21–29	Dry	922	C 893-922
Sam Hindman	Fisher	1	12– 1–27	Dry	4,600	
Humble O. & R. Co.	Meyers Fee	4	11–20–27	100	3,060	
Humble O. & R. Co.	Meyers Fee	5	–28	100	3,000	
Mount Belvieu O. Co.	Williams, M.	1	5– 1–28	Dry	4,556	
McAlbert	Woodward	1	9–16–29	700	5,132	H. L. 4,925-4,974
McAlbert	Woodward	2	9–13–29	1,800	5,252	H. L. 4,968-5,022
McAlbert	Woodward	3	11–14–29	1,800	5,323	H. L. 4,923-4,963
Moody-Humphreys	Collier	1	10–11–29	850	5,083	H. L. 4,760-4,830
Moody-Humphreys	Collier	2	10–16–29	700	5,134	H. L. 4,836-4,877
Moody Corp.	Ilfrey	1	8– 5–29	2,694	5,140	H. L. 4,789-4,849
Moody Corp.	Ilfrey	2	11–21–29	200	5,184	H. L. 4,785-4,843
Rexall Pet. Co.	McLean	1	5–10–29	Dry	3,908	
Rexall Pet. Co.	McLean	2	7–25–29	1,500	5,259	
Rexall Pet. Co.	McLean	3	12–20–29	100	5,226	

TABLE I—*Continued*

Operator	*Tract*	*Well Number*	*Date Completed*	*Barrels Initial Production*	*Feet Total Depth*	*Remarks (Figures in Feet)*
Rexall Pet. Co.	McLean	4	8- -29	294	5,174	H. L. 4,884-4,946
Rexall Pet. Co.	Smith	1	12-30-29	80	2,150	
Rexall Pet. Co.	Shaw	1	3-16-29	650	5,207	C 2,044-2,090 H. L. 4,874-4,926
Republic Prod. Co.	Kirby Pet. Co.	1	7-27-29	3,420	5,194	H. L. 4,916-4,956 Discovery well on SE. flank
Republic Prod. Co.	Kirby Pet. Co.	2	9-21-29	580	5,351	H. L. 5,023-5,080
Republic Prod. Co.	Kirby Pet. Co.	3	1-11-30	60	5,335	H. L. 4,997-5,074
Sinclair O. & R. Co.	McKinney Fee	1	1- 1-30	Dry	5,958	H. L. 5,070-5,128
Sinclair O. & R. Co.	Wilburn, J.	1	10-13-29	510	5,228	H. L. 4,903-4,967
Sinclair O. & R. Co.	Wilburn, J.	2	1-23-30	1,558	5,160	H. L. 4,810-4,880
Sun Oil Co.	Chambers Co. AA	1	6- 7-29	250	5,677	
Sun Oil Co.	Chambers Co. AA	2	6-24-29	2,000	5,489	H. L. 5,010-5,065
Sun Oil Co.	Chambers Co. AA	3	9- 1-29	2,503	4,666	
Sun Oil Co.	McKinney Fee	1	9-30-29	500	5,346	H. L. 5,015-5,065
Sun Oil Co.	McKinney Fee	2	11-16-29	Dry	5,730	
Sun Oil Co.	Wilburn, J	1	11- 6-29	960	5,361	H. L. 4,963-5,033
Sun Oil Co.	Wilburn Fee	1	1- 6-30	Dry	5,456	H. L. 5,034-5,086
Sun Oil Co.	Wilburn Fee	2	12-29-29	1,020	5,314	H. L. 4,920-4,982
Talbert & Markle	Ilfrey	1	5-18-29	1,700	5,190	H. L. 4,919-4,967
Talbert & Markle	Schilling	1	7- 2-29	850	5,196	
Texas Company	Wilburn	1	11-18-29	175	5,177	H. L. 4,791-4,850
Texas Company	Wilburn	2	11-20-29	712	5,112	H. L. 4,711-4,770
Texas Company	Wilburn	3	10-31-29	728	5,101	H. L. 4,720-4,777
Dr. Thompson	Wilburn	1	10-16-29	1,000	5,084	H. L. 4,725-4,787
Unice Oil Co.	Feldman-Gulf	1	6-10-29	600	5,231	C 2,120-2,170 H. L. 4,898-4,973
Yount-Lee Oil Co.	Chambers Co. AA	1	1-29-29	4,700	5,318	H. L. 4,869-4,964 Oligocene sand discovery well on S flank
Yount-Lee Oil Co.	Chambers Co. AA	2	3-27-29	1,125	5,329	H. L. 4,883-4,967
Yount-Lee Oil Co.	Chambers Co. AA	3	4- 8-29	1,200	5,329	
Yount-Lee Oil Co.	Chambers Co. AA	4	9-21-29	Dry	8,184	H. L. 5,473-5,559
Yount-Lee Oil Co.	Chambers Co. AA	5	5- 3-29	Dry	2,570	S 2,456-2,570
Yount-Lee Oil Co.	Chambers Co. AA	6	6-20-29	1,680	5,002	
Yount-Lee Oil Co.	Chambers Co. AA	7	8-16-29	2,310	5,302	H. L. 4,888-4,954
Yount-Lee Oil Co.	Chambers Co. AA	8	10-27-29	100	5,236	H. L. 4,922-4,981
Yount-Lee Oil Co.	Chambers Co. AA	9	11-23-29	1,900	4,841	
Yount-Lee Oil Co.	Kirby Pet. Co.	1	10-25-29	Dry	7,512	H. L. 5,234-5,312
Yount-Lee Oil Co.	Phillips	1	12-21-29	1,290	5,294	
Yount-Lee Oil Co.	Richardson	1	12-20-28	10	2,075	
Yount-Lee Oil Co.	Richardson	2	1-25-29	30	2,080	
Yount-Lee Oil Co.	Richardson	3	2-23-29	Dry	2,217	
Yount-Lee Oil Co.	Richardson	4	3-30-29	Dry	2,279	
Yount-Lee Oil Co.	Woodward	1	9-13-29	585	5,459	H. L. 5,053-5,122
Yount-Lee Oil Co.	Woodward	2	10- 7-29	1,890	5,347	H. L. 4,947-5,002
Yount-Lee Oil Co.	Woodward	3	10-31-29	2,440	5,364	H. L. 4,928-4,984
Yount-Lee Oil Co.	Woodward	4	12- 1-29	630	5,347	H. L. 4,955-5,008
Yount-Lee Oil Co.	Woodward	5	12-21-29	560	5,350	H. L. 4,941-4,997

than 200,000 barrels each during their flowing life, and a few wells considerably more. Wells settle to pumpers with production varying from 75 to 300 barrels. The life of these pumpers can not yet be accurately estimated. The gravity of the oil ranges from 26° to 28° Bé.

The Humphreys Corporation's Kirby A-8, on the northwest flank, has produced 316,500 barrels of oil in the past 39 days from a sand several hundred feet lower in the Oligocene section than the sand which is producing on the opposite flank. It is still flowing 6,000 barrels daily at the time this article is written. The production record of the well indicates that this lower sand will be even more prolific than the 5,100-foot zone already developed on the south and east flanks.

Table I shows well histories.

Distillation tests of oil from the 5,100-foot zone on the east and the 6,400-foot zone on the northwest are shown in Table II.

This crude, in common with most other Gulf Coast crudes, is desirable on account of its lubricating stock and the anti-knock quality of its gasoline.

For the past few months Barbers Hill has equalled Spindletop in daily production and is now the leading coastal salt dome in production. The daily average production by weeks is platted on the graph shown in Figure 10.

Companies having pipe lines to the field are the Liberty, Humble, Sun, and Gulf pipe line companies. The field is within 12 miles of the Houston ship channel, which is accessible to tankers of nearly every size. Most of the oil is run by pipe line to near-by refineries in the Texas Gulf Coast region, or is shipped by tankers to Gulf, Atlantic, or foreign ports. There are thirteen refineries within a radius of 60 miles, with a combined capacity of 513,500 barrels of oil per day.

FUTURE DEVELOPMENT

Twenty-six deep wells are now drilling; twenty-three of these are on proved locations and three are wildcats. The development of the north, west, and south flanks of the dome should proceed in an orderly manner, as leases are held by a few owners in large tracts. The east flank, however, is in certain parts divided into small tracts with different owners, and a rapid development is probable there when deeper flush sands are discovered.

Figure 11 shows formations encountered below the *Heterostegina* limestone in five deep tests on different flanks of the dome.

The Yount Lee Oil Company's Chambers County Agricultural Association No. 4 on the south flank, the Yount Lee Oil Company's

TABLE II

DISTILLATION TESTS BY HOUSTON LABORATORIES, JANUARY 28, 1930

SAMPLE OF OIL FROM HUMPHREYS CORPORATION'S KIRBY H-1; DEPTH, 5,071 FEET

Crude tests	
Gravity	27.3° A. P. I.
Flash	Room temperature
Viscosity	61 at 100° F. Saybolt Univ.
Water	Trace
Pour test	−0° F.
Color	Dark green
Sulphur	0.18 per cent
Tests made on gasoline	
Gravity	54.0° A. P. I.
Color	25
Doctor test	Positive
Initial boiling point	122° F.
Maximum boiling point	434
Summary of yields	
Gasoline	7.7 per cent
Kerosene	5.3 per cent
Gas oil	45.9 per cent
Lubricating oil	25.0 per cent
Fuel oil	15.1 per cent
Loss	1.0 per cent
Total	100.0 per cent

SAMPLE OF OIL FROM HUMPHREYS CORPORATION'S KIRBY A-8; DEPTH, 6,416 FEET

Crude tests	
Gravity	34.2° A. P. I.
Flash	Room temperature
Viscosity	42 at 100° F. Saybolt Univ.
Water	Trace
Pour test	−0° F.
Color	Dark green
Sulphur	0.15 per cent
Tests made on gasoline	
Gravity	55.3° A. P. I.
Color	25
Doctor test	Negative
Initial boiling point	110° F.
Maximum boiling point	434
Summary of yields	
Gasoline	23.6 per cent
Gas oil	45.5 per cent
Lubricating oil	15.0 per cent
Fuel oil	15.0 per cent
Loss	0.9 per cent
Total	100.0 per cent

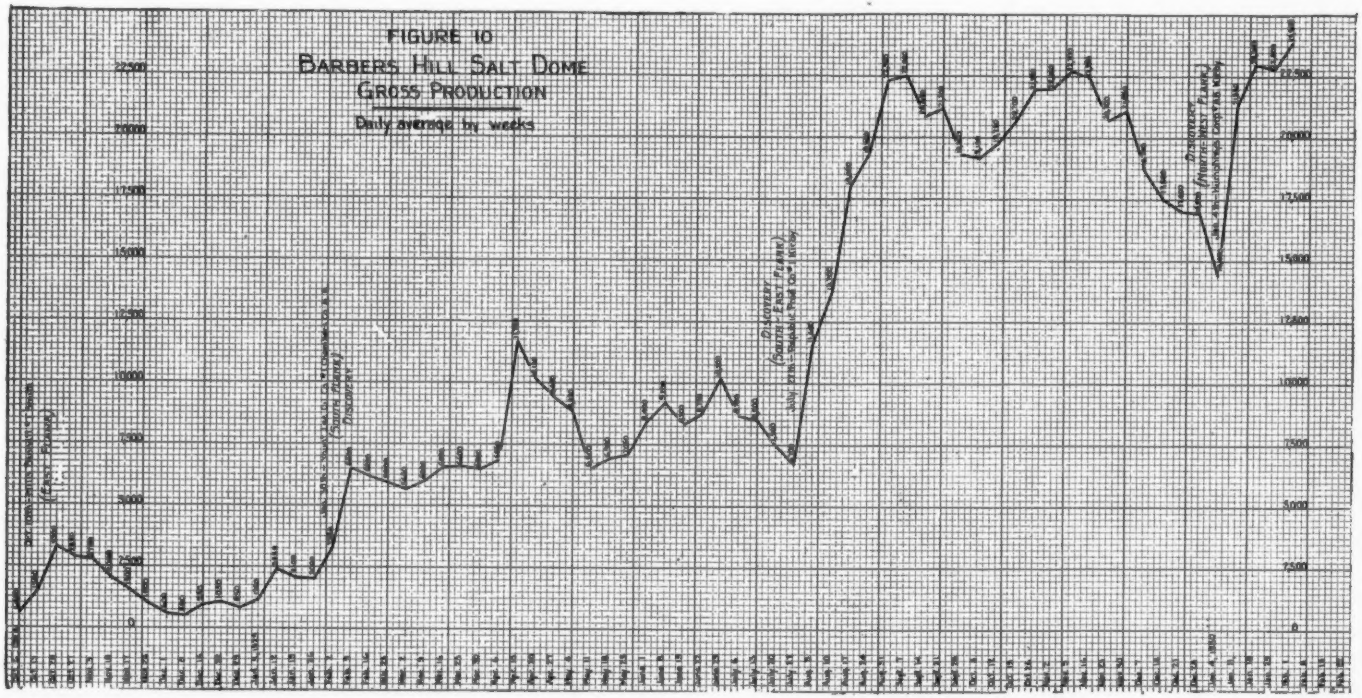


FIGURE 10
BARBERS HILL SALT DOME
GROSS PRODUCTION
Daily average by weeks
Discovery
(South Flank)
Discovery
(South-East Flank)
Discovery
(North-West Flank)
(East Flank)
22500
20000
17,500
15,000
12,500
10000
7500
5000
2500
0

FIG. 10

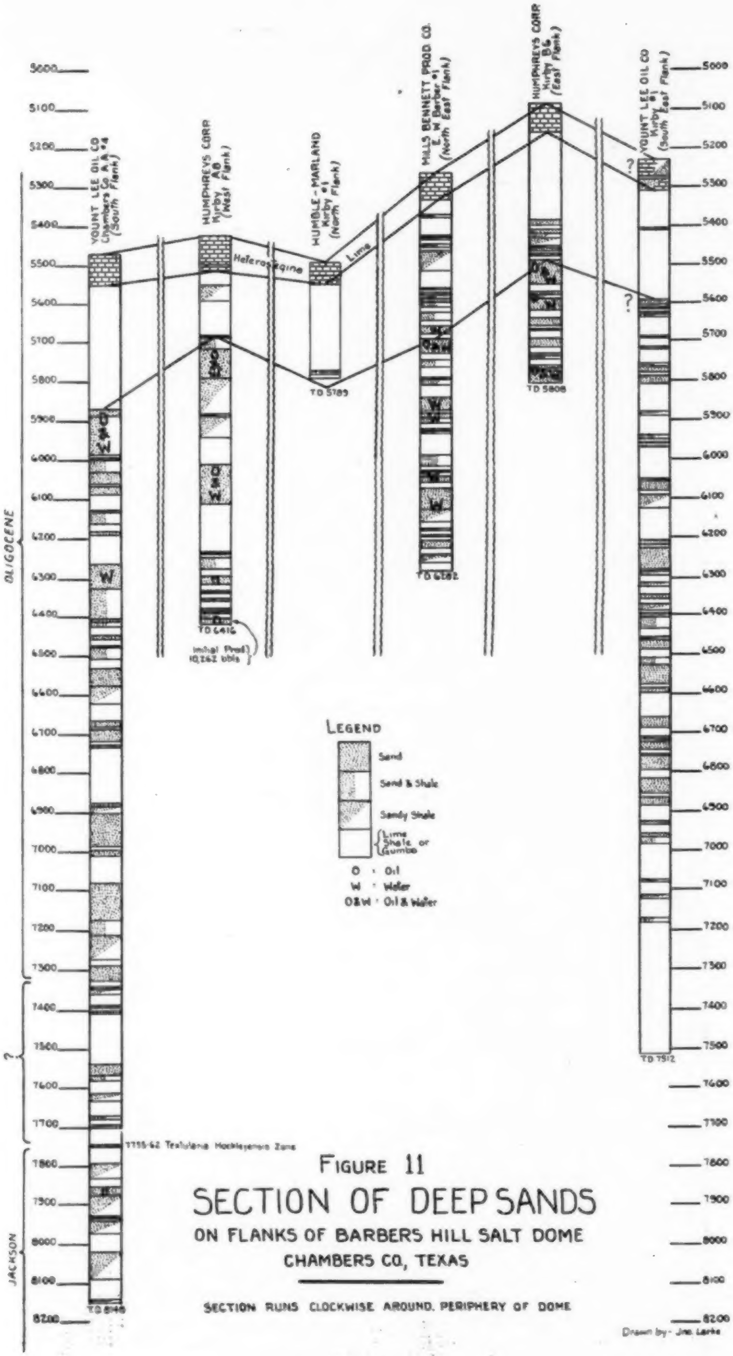

YOUNT LEE OIL CO
(South Flank)
HUMPHREYS CORP
Kirby A8
(West Flank)
HUMBLE - MARLAND
Kirby #1
(North Flank)
MILLS BENNETT PROD CO.
(North East Flank)
HUMPHREYS CORP
Kirby B6
(East Flank)
YOUNT LEE OIL CO
(South East Flank)
Heterostegina
Lime
OLIGOCENE
JACKSON
LEGEND
Sand
Sand & Shale
Sandy Shale
Lime Shale or Gumbo
O - Oil
W - Water
O&W - Oil & Water
FIGURE 11
SECTION OF DEEP SANDS
ON FLANKS OF BARBERS HILL SALT DOME
CHAMBERS CO, TEXAS
SECTION RUNS CLOCKWISE AROUND PERIPHERY OF DOME

FIG. 11

Kirby No. 1 on the southeast flank, and the Humphreys Corporation's Kirby A-8 on the northwest flank show a series of alternating thick sands and shales in the Oligocene, extending from 1,400 to 1,500 feet below the 5,100-foot pay zone. One of these lower sands mentioned has already proved to be prolific, and it is probable that several of the other sands will be productive if found structurally high, close to the dome. The Jackson formation, which is already highly productive on several other salt domes, can be reached by deep wells. The withdrawal of oil from Barbers Hill will be aided in exploratory wells to the deep sands by torsion-balance surveys. The development of the directional survey of wells, making possible the close determination of the position of the bottom of each hole, should reduce the number of dry holes at the dome and allow a minimum number of wells per acre to drain the pay sands effectively. These two methods should lessen considerably the cost of removal of the oil. The drilling depth, the large size of wells, the many sand bodies with seeming regularity, the size of tracts, and the accessibility by water to a world market point to Barbers Hill as being a large continuous producer for many years.

DISCUSSION

Donald C. Barton, Houston, Texas: The topographic expression of the Barbers Hill salt dome very strongly suggests secondary differential uplift later than the main uplift. There is a large low mound which is coextensive with the whole dome. The main part of the conspicuous mound, however, covers a somewhat smaller area and is central slightly west of the geometric center of the dome. On the New Iberia dome, drilling has shown the presence of a salt spine which rises 1,500 feet above the general level of the salt. I have always interpreted this spine as due to differential uplift subsequent to the main uplift and have interpreted the secondary mound, such as that at Vinton and this at Barbers Hill, as due to differential uplift subsequent to the main uplift of the dome. It seems to me possible that the more or less passive material east of the area of secondary upthrust has been tilted slightly eastward by that upthrust and that this tilting has caused the slight over-hanging of the cap and salt on the east edge of the Barbers Hill dome.

DIXIE OIL POOL, CADDO PARISH, LOUISIANA[1]

H. K. SHEARER[2] and E. B. HUTSON[2]
Shreveport, Louisiana

ABSTRACT

The Dixie oil pool is really a southeast extension of the old Caddo oil field, about 3½ miles from the old producing area and within 10 miles of the city of Shreveport. It was discovered in April, 1929, by the D. C. R. Oil Company (D. C. Richardson). By the end of 1929, thirty-seven producing wells and thirty-two dry holes had been drilled within a 3-mile radius.

The wells penetrate the normal section of Eocene and Upper Cretaceous formations. The oil is produced from the basal sand of the Tokio formation, just above the unconformable contact with the Lower Cretaceous upper red beds of the Trinity group. No oil has been produced from the Lower Cretaceous beds in this area.

The Dixie pool is on the Sabine uplift, but the local structure is only a terrace on a slight anticlinal nose, with oil accumulation in sand lenses deposited in basins in the Lower Cretaceous surface. The lenticular condition of the sand has caused a large percentage of dry holes.

Features of the geologic history of the Dixie area and the older Caddo field, as shown by recent deep drilling and geological investigations, are briefly discussed.

In 1929 the Dixie pool produced 588,415 barrels of oil, all of approximately 42° gravity, valued at more than $1,000,000. Future production depends largely on additional drilling; hence, it can not be closely estimated.

INTRODUCTION

The Dixie extension of the Caddo oil field is located in the northwestern part of T. 19 N., R. 14 W., Caddo Parish, Louisiana, which is about 10 miles north-northwest of Shreveport, 3 miles south of Dixie, and 3½ miles southeast of the nearest producing wells in the old Caddo field (Fig. 1).

Although this field is comparatively small, both in area and production, it is of importance in showing depositional and structural conditions and possibilities of oil production on the flanks of major structures in north Louisiana, at locations which previously would not have been considered favorable.

The productive area of the Dixie field is in the Red River bottom and was covered by the waters of Sodo Lake during the Red River raft

[1]Read before the Association at the New Orleans meeting, March 20, 1930. Manuscript received by the editor, February 24, 1930.

Published by permission of the Standard Oil Company of Louisiana, S. C. Stathers, chief geologist.

[2]Standard Oil Company of Louisiana.

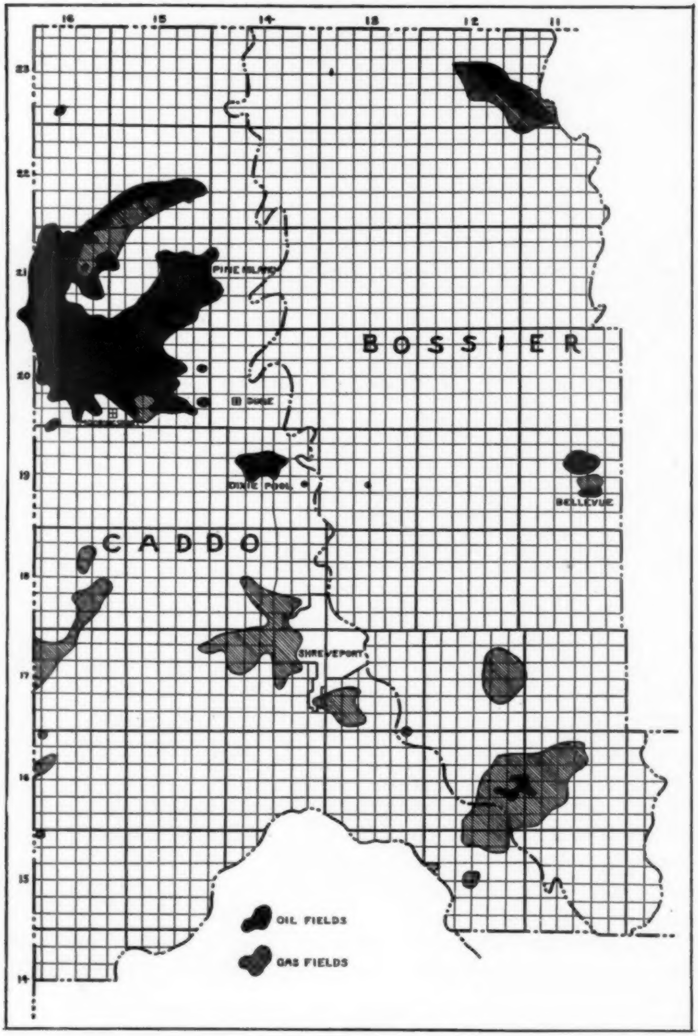


FIG. 1.—Map of Caddo and Bossier parishes, Louisiana, showing the location of the Dixie oil pool in relation to other oil and gas fields. Width of area mapped, approximately 38 miles.

period within the past century. The ground elevation of the entire area is between 170 and 175 feet. The land is partly drained by canals and is largely in cultivation, but parts even a foot or two below the average level are still swampy woods. Because of this late flooding and deposition, the material seen at the surface is all Recent or possibly Port Hudson in age, and there is no evidence as to the structure of the underlying Eocene and Cretaceous beds.

The writers wish to make acknowledgment for helpful suggestions and criticism to S. C. Stathers of Shreveport, Louisiana; also to the many geologists and paleontologists whose published and unpublished work has contributed to the general fund of knowledge of the geology of northern Louisiana.

HISTORY OF DEVELOPMENT

The wells drilled in this area prior to the discovery of the Dixie field are shown in the accompanying list (Table I). Drilling was commenced as early as 1914, and was stimulated by the discovery of the Homer and Bull Bayou oil fields in 1919 and 1920, at which time several wells were completed near Dixie which could have been made into small pumpers.

Although geologists had known for many years that the Nacatoch sand structure shows a broad anticlinal nose on the southeast flank of the Caddo uplift, most of the prospecting was done by independent operators. Credit for the discovery of the field is due principally to D. C. Richardson, but the Standard Oil Company of Louisiana, Gulf Refining Company, Ohio Oil Company, and Palmer Corporation purchased leases from him to assist in financing the discovery well. Before this well was completed, an interest in Richardson's remaining leases was purchased by the Standard Oil Company of Louisiana, and this company drilled all subsequent wells on the combined leases.

The first commercial producer is located on the S. S. Hunter estate, in the NW. ¼, NW. ¼, Sec. 17, T. 19 N., R. 14 W. In drilling this well, Richardson used modern methods of exploration and carefully cored all known and suspected oil and gas horizons. A drill-stem test on March 24, 1929, showed 27 thribbles of 39° gravity oil in 40 minutes from depths ranging from 2,390 to 2,422 feet. Because of the small lenses of oil sand interbedded with shale, it is possible that the producing zone would have been passed, and only a showing of oil recorded, had the old methods of drilling wildcat wells been employed. After casing was set, this well made a flow of 150 barrels in 13 hours on April 28, and was officially completed May 10, 1929, blowing with air, 125 barrels per day.

TABLE I

LIST OF WELLS DRILLED AROUND DIXIE AREA BEFORE DISCOVERY OF COMMERCIAL PRODUCTION

	COMPANY DRILLING	NAME OF FARM	NO.	LOCATION	TOTAL DEPTH	DATE COMPLETED	REMARKS
1	Busch-Everett	Glassell	1	30-20N-14W	2353	1909	4 million cu. ft. gas in Nacatoch. 5 million gas and S. W. at 1886 ft., Oil shows 2150–2350.
2	Standard Oil Co. of La.	Cole	1	25-19N-15W	2794	1914	Good oil show, 2455 ft.
3	Parker & Edwards	Caldwell	1	29-19N-14W	2485	1914	Tested S. W., 2478 ft.
4	Sodo Lake Oil Co.	Slattery	1	15-19N-15W	2435	1914	Oil sand in "Woodbine".
5	Sodo Lake Oil Co.	Slattery	2	15-19N-15W	2412	1914	
6	Arkansas Fuel Co.	Dillon	1	18-19N-14W	2451	1914	S. W. flow from sand at 2424–2426 ft.
7	Hunter, Norris et al.	Hunter	1	9-19N-14W	2530	1915	Tested S. W., 2477–2530 ft.
8	A. W. Baird, Tr.	Dickson	1	31-20N-14W	2384	1916	Oil shows at 2174 and 2311, S. W. at 2384 ft.
9	Baird et al.	Van Cleve	1	24-19N-15W	2760	1916	S. W. and a little gas at 2436 ft.
10	R. L. Layne	Levee Board	1	10-19N-15W	2361	1918	Oil show at 2270 ft., tested S. W.
11	Ark. Nat. Gas Co.	Levee Board	32	24-19N-15W	2840	1918	Oil show at 2275–2337 ft., dry at 2840 ft.
12	Caddo La. O. & G. Co.	Dillon	1	20-19N-14W	2394	1919	Pumped 10 to 25 bbl. of 45° oil from "Woodbine" sand at 2386–2394 ft.
13	Caddo La. O. & G. Co.	Dillon	2	20-19N-14W	2545	1919	Swabbed for 3 days, showed 5-8 bbl. of oil and 60-75 bbl. S.W.
14	Boisseau et al.	Fullilove	1	21-19N-13W	2613	1920	Oil and gas show in "Blossom" at 2020 ft.; oil formation at 2585–2597, made 5 or 6 bbl. per day on pump.
15	Boisseau et al.	Fullilove	2	22-19N-13W	2693	1920	Dry.
16	Boisseau et al.	Fullilove	3	21-19N-13W	2638	1920	Tested dry at 2616 ft.
17	Homer-Union Oil Co.	Scott	1	35-19N-13W	2785	1920	Gas show at 956 ft., S. W. at 2505 ft.
18	Bill Rowe Oil Co.	McCullough	1	26-19N-13W	2750	1920	No shows reported.
19	Invaders O. & R. Co.	Ellerbee	1	34-19N-14W	2830	1920	Tested S. W. at 2774 ft.
20	Wasson O. & G. Co.	Wasson	1	23-19N-15W	2444	1920	Tested 1,729,000 cu. ft. gas at 2434–2444 ft.
21	Wasson O. & G. Co.	Wasson	2	26-19N-15W	3030	1920	Tested S. W. in Nacatoch and below 2400 ft.
22	Oregon Oil Co.	Oden	1	27-19N-14W	3514	1922	Oil and gas show at 2459 ft.
23	Collins et al.	Gray	1	28-19N-13W	3318	1923	Tested S. W. at 2601 ft.
24	Perkins et al.	McFarland	A-1	18-19N-13W	2626	1923	Oil shows at 988 and 2557 ft., tested S. W.
25	Collins et al.	Levy Realty Co.	1	23-19N-14W	2609	1924	Swabbed 5 bbl. oil per day with considerable salt water at 2549 ft.
26	Woodley & Collins	McVea	1	23-19N-14W	2675	1925	Oil shows at 956 and 2554 ft., tested dry.
27	Woodley & Collins	Kilburn	1	18-19N-13W	2655	1926	Oil shows at 986 and 2521 ft., tested dry.
28	Gulf Refining Co.	Byrd	1	2-19N-14W	3903	1926	Oil shows at 966 and 2850 ft., tested S.W. at 2854 ft.
29	Woodley & Collins	McVea	A-1	23-19N-14W	2610	1928	Tested small show of oil and gas at 2570 ft.
30	Gulf Refining Co.	Attaway	1	1-18N-15W	4568	1928	No shows reported.
31	B. C. Richardson	Hunter Est.	1	17-19N-14W	2422	1929	Discovery well, 125 bbl. of oil first day.

Since April, 1929, 74 wells have been drilled within a 3-mile radius. Including the discovery well, there were 37 oil producers, 32 dry holes, and 5 wells not yet completed on January 15, 1930. Of these, 34 producers and 19 dry holes are in Secs. 7, 8, 9, 16, 17, and 18, T. 19 N., R. 14 W., which may be considered the field proper. In addition, Secs. 10, 20, and 22 have each 1 small producer, and 13 more dry holes have been drilled in the surrounding area, including 3 in T. 19 N., R. 15 W., and 3 in T. 20 N., R. 14 W.

STRATIGRAPHY

The generalized stratigraphic column is shown in Table II.

QUATERNARY (PLEISTOCENE AND RECENT)

As previously mentioned, the surface formation in the Dixie area is a lake and flood-plain deposit, consisting of red clay and fine red sand. Immediately underlying the Recent deposit are some sand, clay, and gravel probably deposited during the Port Hudson stage of the Pleistocene, but derived largely from the Pliocene Citronelle sands and gravels which are now found only as remnants capping the higher hills in surrounding areas. Surface sands and gravels of these Quaternary deposits are reported in some well logs to a depth of 100 feet or a little more, this thickness evidently being due to the filling of an old river channel.

TERTIARY (EOCENE)

Wilcox formation.—The Wilcox formation crops out in hilly areas surrounding the Dixie field. In the field this formation is represented by 200 - 300 feet of sediments. The entire formation is non-marine in this area and consists of alternating beds of gray, soft, coarse- and medium-grained, non-calcareous sand and subordinate layers of gray or brownish, carbonaceous, micaceous, non-calcareous shale. Thin beds of lignite and carbonized wood are common, especially in the upper part. Boulders of siderite and of hard, gray, very calcareous sandstone are present throughout the formation. Water is plentiful in the sands, but it ordinarily contains considerable amounts of sodium chloride or sulphur.

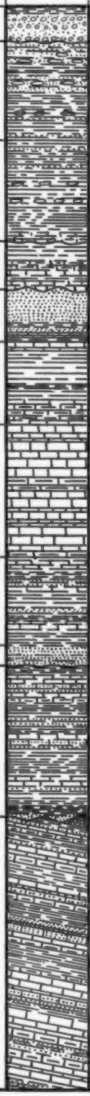
Midway formation.—The contact between the Wilcox and Midway formations is not definitely known, as both the lower Wilcox and the upper Midway consist of interbedded sand and shale, and all wells were drilled rapidly through this part of the section, without being cored or without particular attention to the changes in formation.

The upper sandy Midway beds grade downward into gray, coarse-grained, micaceous shale, and this into almost black, hard, non-cal-

TABLE II

GENERALIZED STRATIGRAPHIC COLUMN IN DIXIE AREA, CADDO PARISH, LOUISIANA

FORMATION		SECTION	FEET	CHARACTER OF ROCKS
PLEISTOCENE AND RECENT			100	Sand, gravel and red clay.
EOCENE	WILCOX FORMATION		200-300	Gray or brown sand and shale with some lignite and hard boulders.
EOCENE	MIDWAY FORMATION		300-400	Dark gray shale with siderite boulders, some limestone and marl near base.
	UNCONFORMITY			
UPPER CRETACEOUS	ARKADELPHIA FORMATION		150	Gray shale and marl, thin beds of sand and limestone.
	UNCONFORMITY			
UPPER CRETACEOUS	NACATOCH FORMATION		150	Hard and soft sand at top, sandy limestone, sandstone and shale at base.
UPPER CRETACEOUS	SARATOGA CHALK AND MARLBROOK FORMATION		240	White chalk. Gray clay, shale and marl.
UPPER CRETACEOUS	ANNONA CHALK		400	White chalky limestone with some gray shale and marl.
UPPER CRETACEOUS	OZAN FORMATION		340	Gray shale, sandy shale, sand and marl. Sand member at base. "Buckrange" or "Blossom"
	UNCONFORMITY			
UPPER CRETACEOUS	BROWNSTOWN FORMATION AND TOKIO FORMATION		435	Dark gray shale, sandy shale, marl and sand near top. Dark greenish gray shale. Lenticular sand at base.
	UNCONFORMITY			
LOWER CRETACEOUS	TRINITY GROUP		5000 plus	"Upper red beds" consisting of alternating red, brown and greenish gray shale, sandy limestone and calcareous sandstone, 1300 feet plus; with Glen Rose formation, etc. below.



careous, carbonaceous shale, which contains many boulders of siderite. The thickness of about 400 feet which may be definitely referred to the Midway consists mostly of this shale. A small amount of mica is present in some of the beds, and in the shale beds of the lower half of the formation a few arenaceous *Foraminifera* have been found. Among the most common are *Ammobaculites* sp. and *Trochamminoides* sp.

The basal bed of the Midway is gray, hard, very calcareous, fossiliferous shale. West of the Dixie area, this shale grades into a bed of white fossiliferous limestone only 2 or 3 feet thick. A typical fauna is found in the basal Midway. Among the assemblage of *Foraminifera* there are many which have been described from surface exposures in Texas. A few of the forms observed are the following: *Marginulina gardnerae* Plummer, *Frondicularia rugosa* d'Orbigny, *Polymorphina cushmani* Plummer, *Lenticulina midwayensis* Plummer, *Vaginulina gracilis* Plummer, *V. robusta* Plummer, and *Cibicides vulgaris* Plummer.

UPPER CRETACEOUS

Arkadelphia formation.—The lithologic as well as the faunal change is very noticeable in passing from the Midway to the Arkadelphia formation, and this contact is a major unconformity representing a long time interval. However, as both formations consist of materials of nearly the same hardness, reported in drillers' logs as shale, shale and boulders, or gumbo, the contact can not be determined in wells unless samples are available. In the Dixie discovery well, Arkadelphia *Foraminifera* were found in the cuttings 150 feet above the Nacatoch "gas rock;" hence, this may be considered the total thickness of the Arkadelphia. In the Nesbitt *et al.* Leonard No. 1, Sec. 20, T. 19 N., R. 13 W., 4 miles southeast of the producing area, 26 feet of beds above the Nacatoch sand are definitely Arkadelphia, but no samples from higher beds are available.

The dominant materials in the Arkadelphia formation are soft, greenish gray, calcareous, fossiliferous shale and light greenish, fossiliferous marl. Near the base, there is a thin bed of light gray, fairly hard, very calcareous, fossiliferous sandstone which grades downward into limestone. Below this limestone, there is about 15 feet of greenish gray, soft, fossiliferous marl, which is the base of the formation in the Dixie field.

Foraminifera are plentiful throughout the Arkadelphia. Among the forms observed are the following: *Flabellina reticulata* (Reuss), *Globigerina bulloides* d'Orbigny, *Vaginulina trilobata* d'Orbigny, *Bulimina*

pupoides d'Orbigny, *Vaginulina webbervillensis* Carsey, and *Globotruncana rosetta* (Carsey).

Nacatoch formation.—The first distinct break or horizon marker in this area is the top of the Nacatoch sand, commonly called "gas rock." In the producing area this is found at depths ranging from 609 to 684 feet below sea-level. The variations are irregular, with local differences of more than 50 feet between offset wells. This can not be due to structural conditions, because the top of the Nacatoch shows much greater and more irregular relief than the underlying formations; therefore, the variations are due either to lenticular deposition of the Nacatoch sand or to an erosional unconformity between the Arkadelphia and Nacatoch. In the outcrop area in southwestern Arkansas[1] there is evidence of such an unconformity, and it is very probable that the Sabine uplift emerged as an island at the close of the Nacatoch deposition, thus permitting more erosion than in the surrounding synclinal areas.

The minimum thickness of the Nacatoch formation is about 150 feet, but some well logs show as much as 200 feet of sand and gas rock. The upper beds consist of gray and greenish gray, soft, fine- to coarse-grained, calcareous, glauconitic, fossiliferous sandstone, with a few thin beds of gray, fairly hard, calcareous, fossiliferous shale. The lower part consists of alternating beds of gray, hard or soft, calcareous, glauconitic, slightly fossiliferous sands and a few thin beds of light gray, hard, arenaceous, fossiliferous limestone. In the more porous sands of the Nacatoch, showings of oil and small amounts of gas have been found in wells that tested this formation.

Although the Nacatoch is fossiliferous, the fauna is rather sparse and generally poorly preserved. This is especially true of the microfauna. Among the forms that have been observed are the following: *Cythereis hazzardi* Israelsky, *Cythereis costatana* Israelsky, *Cythere ovata* Berry, *Cytheridea monmouthensis* Berry, *Lenticulina navarroensis* (Plummer), *Globotruncana rosetta* (Carsey), and *Anomalina* sp.

Saratoga chalk.—The Saratoga chalk has not been recognized from cores in wells drilled in the Dixie field, but it is probably present and represented by a bed of limestone 10-20 feet thick, which is shown below the Nacatoch in a few of the well logs.

Marlbrook formation.—The thickness of beds referred to the Marlbrook formation (including the Saratoga, if present) is about 240 feet in this area. The upper part consists of dark gray, rather soft, fossili-

[1]C. H. Dane, "Upper Cretaceous Formations of Southwestern Arkansas," *Arkansas Geol. Survey Bull. I* (1929), p. 145.

iferous marl, and the lower beds are gray, hard, arenaceous, calcareous shale. Near the base, the hard shale grades into soft, fossiliferous marl.

A few of the micro-fossils observed in the formation are: *Cythereis ponderosana* Israelsky, *Cythereis communis* Israelsky, *Cytheridea globosa* Alexander, *Anomalina grosserugosa* Gumbell, *Bolivina pliata* Carsey, *Globigerina cretacea* d'Orbigny, and *Gumbelina globulosa* Ehrenberg.

Annona chalk.—The Annona chalk is a very distinctive lithologic unit. It consists of beds of almost pure white chalk; light gray, chalky, fossiliferous limestone; gray, fairly hard, fossiliferous marl; light gray, hard, fossiliferous limestone; and a few thin beds of dark gray, slightly arenaceous shale. Near the base, hard, white, chalky limestone grades into soft gray marl.

The thickness of almost solid chalk is approximately 400 feet. Since the chalk proper is conformable with, and grades upward and downward into, marls of the Marlbrook and Ozan formations, it would be difficult to draw sharp lines of contact even with plenty of samples. In drilling, the reported top and bottom of the chalk depend largely on the personal equation of the driller; therefore, these horizons are of little value for correlation purposes.

Among the fossils of the Annona the following seem to be the most characteristic: *Bolivinoides latticea* (Carsey), *Gyroidina excolata* (Cushman), *Lenticulina macrodisca* Reuss, *Tritaxia tricarinata* Reuss, *Bolivina incrasata* Reuss, *Pullenia coryelli* White.

Ozan formation.—The upper part of the Ozan formation is represented by gray, fossiliferous marl alternating with beds of gray, micaceous shale and greenish gray, slightly calcareous, glauconitic sandstone. Lower in the section is gray, soft, micaceous, fossiliferous shale. The basal part of the formation consists of alternating beds of dark greenish gray, hard, calcareous, slightly carbonaceous shale and greenish, hard or soft, coarse-grained, silty, non-calcareous, glauconitic sandstone. In certain layers of the basal sands numerous specks of a yellowish, fine-textured material have been observed. This may be volcanic ash, but no petrographic study has been made.

The basal sand of the Ozan formation is commonly known as the "Blossom" sand member. It was correlated by Matson[1] as the upper member of the Eagle Ford clay, but is now believed to correspond with the Buckrange sand lentil at the base of the Ozan formation of the Arkansas outcrop section.[2] The thickness of the sand member ranges from

[1]G. C. Matson, "The Caddo Oil and Gas Field," *U. S. Geol. Survey Bull. 619* (1916), pp. 18 and 31.

[2]C. H. Dane, *op. cit.*, p. 59.

60 to 75 feet in the more reliable logs. This is generally drilled with a roller bit and all reported as sand rock, but cores from several wells show that it contains considerable interbedded shale. Variations in the depth and thickness of the "Blossom" sand, as reported in some of the well logs, do not appear reasonable, in view of the fact that no such structural disturbance exists in the underlying beds. These variations are evidently due to incorrect drill-stem measurements, as most of the wells were drilled for speed to about 2,375 feet; then a steel-line measurement was taken and an accurate log kept of the remainder of the hole.

The total thickness of the Ozan formation, from the base of the hard chalk of the Annona to the base of the "Blossom" sand in the discovery well, which may be considered the type log, is 346 feet.

The Ozan in the Dixie field is very sparsely fossiliferous, but the following micro-fossils have been observed: *Cythereis communis* Israelsky, *Cythereis ozanana* Israelsky, distorted forms of *Tritaxia* sp., *Anomalina taylorensis* Carsey, *Globigerina* sp., and *Gumbelina* sp.

Brownstown formation.—No cores from this formation have been examined, but a few cuttings through the interval considered to represent the Brownstown formation show dark gray, fossiliferous shale and marl. A considerable amount of muscovite is present in some of the shale fragments.

Tokio formation.—The total thickness of beds from the basal Ozan sand member to the base of the Upper Cretaceous series is approximately 435 feet, which includes both the Brownstown and Tokio formations. The greater part of the Tokio formation is made up of alternating beds of dark gray, hard, calcareous, slightly micaceous, fossiliferous shale; thin layers of gray, fine-grained, slightly glauconitic, calcareous sandstone; and dark greenish gray, hard, fine-grained, calcareous or non-calcareous shale.

The oil-producing horizon in the Dixie field is the basal Tokio. The lower 20 or 30 feet of this formation consists of alternating thin beds of greenish gray, hard, non-calcareous, carbonaceous shale and brown, medium- or fine-grained, slightly glauconitic, carbonaceous, more or less porous sandstone. The layers of sand range in thickness from a fraction of an inch to several feet. The hardness and porosity of the sand depend on the amount of cementing material present. Where there is only a small amount of calcite cement the sand is ordinarily unconsolidated, and the best wells have been completed in sand of this type.

There is no gravel or basal conglomerate to mark the great unconformity below the Tokio. Only the fine- to medium-grained, lenticular

sands and a little lignitic material indicate the short period of shallow-water deposition when this area once more sank below sea-level.

This producing zone was called the "Woodbine sand" in earlier reports, and the term is still in common use. The "Woodbine" sand of the drillers includes not only the basal Tokio, but also some sands near the top of the Lower Cretaceous which have been very productive in some parts of the old Caddo field. However, there is no evidence of the presence of the true Woodbine formation, which is between the Tokio and the top of the Trinity formation in the Arkansas outcrop section, and consists chiefly of gravel and re-worked volcanic material. It is probable that the Woodbine formation was never deposited over the higher part of the Sabine uplift, which must have been an island during that time interval.

Above the producing horizon the Tokio formation is somewhat fossiliferous. Among the micro-fossils are: *Vaginulina* sp., *Marginulina* sp., *Frondicularia elongata* White, *Anomalina taylorensis* Carsey, *Lenticulina rotulata* (Lamarck), *Cytheropteron tokiana* Israelsky, and *Cythereis bicornis* Israelsky. In the shale layers of the producing zone are a few specimens of *Globigerina cretacea* d'Orbigny, *Gumbelina globulosa* Ehrenberg, and *Anomalina eaglefordensis* Moreman.

LOWER CRETACEOUS

Trinity group.—The Lower Cretaceous section encountered in wells drilled in the Dixie field consists of greenish gray, hard, calcareous, carbonaceous, arenaceous, fossiliferous shales; thin beds of red or brown, calcareous or non-calcareous shale; light greenish gray, medium hard, fine-grained, calcareous sandstone; and light gray, hard, fossiliferous limestone.

Some showings of oil have been found in the sand beds here described, but these sands are generally too tightly cemented to produce oil. Most of the wells in and around the producing area which found poor sand conditions and tested dry in the basal Tokio were deepened from 100 to 400 feet into the Lower Cretaceous and again tested, but only one of the smaller wells, the Palmer Corporation's Hunter No. 2, Sec. 8, T. 19 N., R. 14 W., made any considerable increase after drilling into the Trinity beds. Some of the deepened wells showed more or less salt water.

Although the greenish gray shales in the Lower Cretaceous and those in the Tokio formation above are similar lithologically, there is a very distinct faunal change. The following fossils have been observed in the Trinity beds: *Cytheridea trinitiensis* Vanderpool, *Paracypris weather-*

fordensis Vanderpool, *Ammobaculites* sp., *Quinqueloculina* sp., *Polymorphina* sp., and *Glauconia branneri* Hill.

The Lower Cretaceous beds penetrated by wells in the Dixie field belong to the upper red-beds division of the Trinity. The beds known as Trinity on and around the northern part of the Sabine uplift are so thick and so varied in character that they must be considered a group rather than a single formation.[1] The generalized section, described from the top downward is subdivided as follows.

1. The upper red beds, which have not been given a formation name in well logs, correspond in age relations with the Paluxy sand of the outcrop section described by Vanderpool. They contain some beds of red or brown shale, but consist largely of marine beds of greenish fossiliferous shale and hard limestone. The only well in T. 19 N., R. 14 W. which was drilled through this formation is the Gulf Refining Company's Byrd No. 1 in Section 2, which was completed at a total depth of 3,903 feet, in 1926. This had the upper red beds to a depth of 3,342 feet, or a thickness of 838 feet below the probable top of the Lower Cretaceous. Near the southwest corner of this township is the Gulf Refining Company's Attaway No. 1 in Sec. 1, T. 18 N., R. 15 W., having a total depth of 4,568 feet, which found at least 1,250 or 1,300 feet of upper Trinity beds down to 3,825 feet. These wells indicate a rather steep south dip of the Trinity, with corresponding thickening of the truncated upper formation.

2. The Glen Rose formation proper consists chiefly of hard gray limestone at the top, followed by several hundred feet of anhydrite, and this by a thick section of interbedded limestones, shales, and sands, but without any red beds. The total thickness is 1,600 -1,800 feet. Wells have been drilled through these beds on the Bellevue and Cotton Valley structures, as well as in the Pine Island area of the Caddo field. The beds below the anhydrite are producing light oil and gas at Pine Island and Cotton Valley.

3. The lower red beds, a non-marine formation of sand and shale, mostly red, contain a great deal of sand and some lignite. Several deep wells in the Pine Island area have reached the lower red beds, but only two wells in Louisiana have been drilled through them, namely, the Dixie Oil Company's Dillon No. 92, Sec. 13, T. 21 N., R. 15 W., Pine Island, reaching a total depth of 6,351 feet, and the Humble Oil and Refining Company's Bliss and Weatherbee No. 30, Sec. 15, T. 19 N., R.

[1] H. C. Vanderpool, "A Preliminary Study of the Trinity Group," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 11 (November, 1928), pp. 1069-94.

11 W., Bellevue, reaching a total depth of 5,302 feet. These wells both show a thickness of slightly more than 2,000 feet. The Magnolia Petroleum Company's McCook and Hibbler No. 1, Sec. 22, T. 21 N., R. 10 W., Cotton Valley, at a total depth of 7,006 feet, had penetrated only 1,400 feet of the lower red beds.

4. The lower marine beds, consisting of greenish gray limestone and hard green shale, with some marine fossils, have been reached only by the Dixie Oil Company's and Humble Oil and Refining Company's wells already mentioned.

The Dixie Oil Company's well was drilled more than 4,100 feet into the Trinity without reaching the bottom, and this thickness does not include any of the upper red beds, which had been removed by pre-Tokio erosion at this location. It is thus evident that the Trinity group has a total thickness of more than a mile.

The Fredericksburg and Washita formations of the Lower Cretaceous, which overlie the Trinity, have not been found, and were probably never deposited on the top and east side of the Sabine uplift. These formations come in between the Tokio and the upper red beds of the Trinity along the west flank of the uplift, and thicken westward into Texas.

STRUCTURE

Regional structure.—The Dixie area is located on the east slope and near the top of the major structural "high" known as the Sabine uplift. The Sabine uplift itself is one of the large folds on the great north Louisiana and south Arkansas structural "high," which extends far enough east to include Smackover and other oil fields in Arkansas and the Monroe and Richland gas fields in Louisiana.

The Sabine uplift is now known to be a much more complicated structural feature than was supposed during the original development of the Caddo and DeSoto oil fields. The total area to be included on the uplift is a matter of definition, on which not all geologists are in agreement. The principal axis extends southeast from northern Caddo Parish to DeSoto and Red River parishes. The Caddo, Shreveport, Cedar Grove, Elm Grove, and DeSoto-Red River oil and gas fields are on or near this axis, with the Pleasant Hill, Zwolle, and Blue Lake oil fields of Sabine Parish on the south flank. Near Mooringsport the main axis splits, and a spur extends southwest into Texas, through the Waskom, Bethany, and Panola County fields. The Bellevue dome-like structure lies east of the principal axis, but is connected with it by a saddle, where

the Nacatoch sand is found less than 900 feet below sea-level; hence, this structure may also be considered a part of the Sabine uplift.

The highest points on the top of the Nacatoch sand on the Sabine uplift proper are in and around Sec. 16, T. 20 N., R. 15 W., in the Mooringsport district of the Caddo field, and in and around Sec. 5, T. 12 N., R. 11 W., in the Naborton district of the DeSoto-Red River field, at both of which points the top of the Nacatoch is found less than 550 feet below sea-level. The Bellevue structure is even higher, bringing the Nacatoch up to less than 100 feet below sea-level.

The structure of the other Upper Cretaceous formations is approximately the same as the Nacatoch structure, because any unconformities which exist in the Upper Cretaceous series represent only small time intervals which did not allow any great amount of erosion. However, the Lower Cretaceous structure is entirely different, because the folding affecting the Upper Cretaceous is superposed on more intense folding already present in the Lower Cretaceous.

Bellevue is the highest point structurally on the Lower Cretaceous as well as on the Nacatoch; but on the main axis of the Sabine uplift, the highest Lower Cretaceous structure is in the Pine Island area, in and around Sec. 14, T. 21 N., R. 15 W., which is 6 miles or more northeast of the apex of the Nacatoch structure. This Pine Island Lower Cretaceous "high" is an approximately circular dome. As the Dixie area is on the south-southeast flank of this dome, the local dip of the Lower Cretaceous beds is almost south, although the unconformable upper surface of the Lower Cretaceous dips more nearly east.

Local structure and sand conditions.—As previously mentioned, in the limited area around the Dixie field, contouring on the Nacatoch sand does not show the true structure, because of irregular deposition or unconformity; and the Annona chalk and Ozan sand do not provide satisfactory horizon markers, principally because of lack of care in drilling and keeping measurements. Therefore, the accompanying subsurface structure map (Fig. 2) is contoured on the top of the Lower Cretaceous, which may be taken as the base of the producing sand.

All of the wells drilled by the Standard Oil Company of Louisiana have been cored through the producing sand and into the Lower Cretaceous, which has made it possible to determine the contacts within 2 or 3 feet. The logs of wells drilled by other companies, especially by independent operators, give somewhat less definite information, but the contact can generally be determined with sufficient accuracy by comparison with the Standard Oil Company logs.

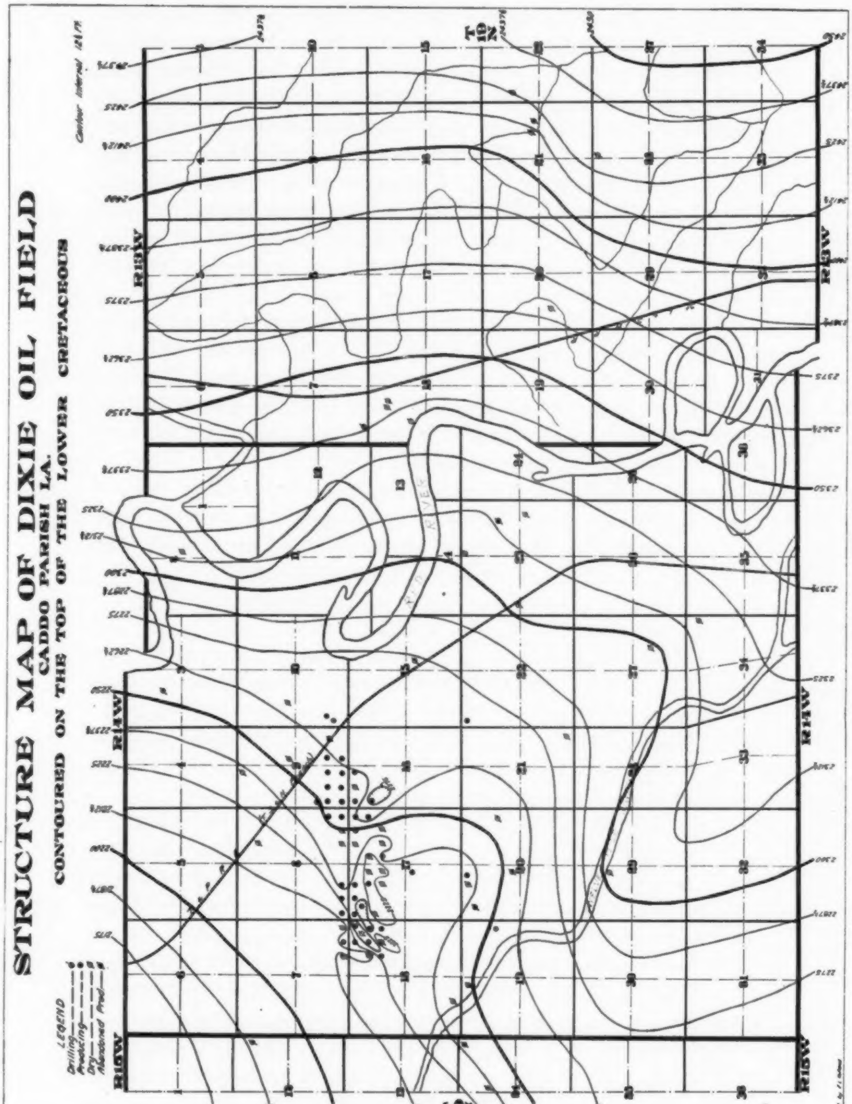


FIG. 2.—Structure map of Dixie oil field. Width of area mapped, approximately 9 miles.

The dip is slight, the average being about 25 feet per mile east-southeast across the area mapped. The structure in the producing area may be described as a terrace on a slight anticlinal nose. The oil comes principally from pockets and lenses of basal Tokio sand, and this basal sand was deposited only in hollows or erosion channels in the surface of unconformity at the top of the Lower Cretaceous. Wells which happened to strike hills or ridges on the Lower Cretaceous surface were dry because of the lack of sand, although they might offset good producers. The relief in detail is only about 30 feet, but the depth of the unconformity below sea-level in producing wells ranges from 2,213 to 2,279 feet, because of a tilt toward the southeast.

The best group of wells in the field are the four around the common corner of Secs. 8, 9, 16, and 17, T. 19 N., R. 14 W., each of which had an initial production between 3,000 and 3,500 barrels per day. The only other well which made more than 3,000 barrels per day is in the northeast corner of Sec. 18, and this is offset by dry holes on two sides, with only small producers in other directions.

On account of the erratic sand conditions, no location can be considered proved in advance of drilling. It is not safe to make projections more than ¼ mile from producing wells, and at best, no new location has much more than an even chance of finding production.

GEOLOGIC HISTORY

The known geologic history of the Caddo area begins in early Cretaceous time. It is inferred that this was a land area during much of the Paleozoic, because there is evidence that the material of the early Pennsylvanian deposits of southwestern Arkansas came from a southern source.[1] At that time a southeastern extension of the Arbuckle Mountains may have continued into Louisiana.

Recent evidence indicates that the Ouachita Mountain folding occurred at a later period than that of the Arbuckle Mountains. Melton[2] presents evidence that most, if not all, of the Ouachita disturbance occurred in post-early Permian time, which means that it may have continued into the early Cretaceous.

In the north Louisiana area there was a somewhat rapid downwarping during the early Cretaceous, which probably accompanied the latter

[1] H. D. Miser and A. H. Purdue, "Geology of the De Queen and Caddo Gap Quadrangles, Arkansas," *U. S. Geol. Survey Bull. 808* (1929), pp. 133-35.

[2] F. A. Melton, "Age of the Ouachita Orogeny and its Tectonic Effects," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 1 (January, 1930), pp. 57-72.

phase of uplift in the Ouachita Mountains on the north, and permitted the deposition of the great thickness of Lower Cretaceous Trinity beds known to exist. Possibly the earlier part of the Permian Red-beds extended much farther east than the present distribution, and the rapid erosion and re-deposition of this material in shallow water was the principal source of the 2,000 feet or more of lower red beds in the Trinity. Later the area sank below sea-level, and continued sinking, while the thick Glen Rose limestone was deposited. During a part of this time the synclinal basin was cut off from the open sea, and the water became highly concentrated, which killed most forms of animal life and caused the deposition of gypsum or anhydrite interbedded with limestone and marine shales through a thickness of 500 feet. After this, communication with the sea was re-established, while the rate of depression decreased and the water became very shallow, so that the alternating sands, limestone, and red shales of the Trinity upper red beds were laid down.

Then, about the end of Trinity time, a tilting movement toward the west took place. The East Texas syncline remained below sea-level while the Fredericksburg and Washita formations were deposited, but the Sabine uplift and the area on the east became land, and erosion probably became active immediately.

Near the end of the Lower Cretaceous, and probably in early Upper Cretaceous time, there was a period of igneous activity which seems to have been a final result of the Ouachita mountain-building movements. Plugs of basic igneous rocks of this age are found near Murfreesboro, Magnet Cove, Bauxite, and Little Rock, Arkansas, and intrusive or extrusive rocks of similar character have been encountered in wells in Cleveland, Drew, Ashley, and Chicot counties in southeastern Arkansas.[1]

It is probable that the large, circular, dome-like structures of north Louisiana, such as Pine Island, Bellevue, Cotton Valley, and Homer, were thrust up by deep-seated igneous intrusives during this period, because they are much larger than any known salt-dome structures, and obviously could not have been produced by ordinary compressional folding. Whatever the cause, the Lower Cretaceous beds at Pine Island were raised about 1,500 feet higher than in surrounding areas, and at Bellevue the uplift amounted to approximately 2,000 feet.

During and after the period of uplift, these structurally high areas were eroded almost to base level. Erosion continued during the

[1] C. L. Moody, of the Ohio Oil Company, Shreveport, Louisiana, has made the most complete investigation of the igneous rocks found in Arkansas wells, but has not published any description.

Woodbine period of Upper Cretaceous time, so that just before the next depression and the beginning of Tokio deposition the Sabine uplift was a low, flat island. As there was no high land near to serve as a source of coarse sediment along the shore of the advancing sea, the lower part of the Tokio is dominantly shale. The small amount of sand present was worked over and deposited in the small valleys or basins which existed in the Lower Cretaceous surface. Re-worked Trinity ostracods have been observed in sands underneath which are shale layers of Tokio age. Carbonaceous material is disseminated through the sand and shale beds and in some places a seam of lignite has been observed. This indicates a rather luxuriant growth of vegetation near the strand line of the Tokio sea. That the area was connected with the open sea most of the time is proved by the presence of marine fossils. The central part of the Pine Island structure was a little higher than the surrounding areas and was the last island to be covered by the sea; hence, practically no sand was deposited there in the basal Tokio, and the so-called "Woodbine" has not yielded any oil in this limited area.

During the remainder of the Upper Cretaceous subsidence was almost continuous, but there were two periods of shallow-water deposition, with a source of coarser materials at the north, when the lower Ozan and Nacatoch sand beds were laid down. There must have been a short interval of emergence which permitted some erosion at the close of the Nacatoch deposition.

Between the deposition of the Upper Cretaceous Arkadelphia formation and the Eocene Midway formation there was a break which represents a considerable period of time, but this unconformity is inconspicuous on account of the similarity of materials, and there is no evidence that any great thickness of beds was removed from the top of the Arkadelphia by erosion.

The greater part of the Midway is marine, laid down in quiet shallow water supplied only with fine clay sediment. At the close of the Midway the sea gradually withdrew toward the south, and a plentiful supply of sandy material was transported from the north to form the non-marine Wilcox formation. The basal marine Claiborne (Cane River formation) is found on all sides of the Sabine uplift, and has probably been removed from the top during the present cycle of erosion. There is no evidence that any formations later than the Claiborne were ever laid down over the uplift, although the Jackson sea extended much farther north in the Mississippi embayment on the east.

The folding in the Eocene beds is in general similar to that in both Upper and Lower Cretaceous, but less intense. A part of the Eocene structure may be due to differential compacting in the thicker deposits off the old structural "highs," but some is undoubtedly due to later movement along the older structural axes. The post-Eocene warping and tilting of all northwestern Louisiana southeastward toward the center of the Mississippi embayment was accompanied by stresses from the southeast, which formed a series of minor northeast-southwest folds, crossing the major axes of the Sabine uplift and other older structures, accompanied by some faulting. For example, a northeast-southwest fault cutting the Eocene formations has been determined by drilling near Rodessa on the northwest flank of the Sabine uplift. These later folds have had some influence on oil accumulation in the sands, and oil found in the Annona chalk in some parts of the Caddo field has evidently migrated and accumulated along post-Eocene faults.

PRODUCTION DATA

The total production of the Dixie field by months from the time of discovery until January 1, 1930, was as follows.

DIXIE FIELD
Production by Months, 1929

	Barrels
May	1,751
June	26,480
July	40,864
August	36,730
September	137,433
October	177,943
November	87,199
December	80,015
Total	588,415

The oil is of the Caddo light type, varying only a fraction of a degree from 42° gravity, and nearly all a little more than 42°. This grade of oil sold for $1.75 per barrel during 1929, giving a total value of $1,029,726.25 for the oil produced On January 16, 1930, the price of this grade of oil was cut to $1.38 per barrel.

The accompanying graphs show the average daily production by weeks for one of the largest wells, the Standard Oil Company of Louisiana's Caddo Parish School Board No. 1, located in the NW. corner of Sec. 16, T. 19 N., R. 14 W. (Fig. 3); and the total daily production and average daily production per well for the entire pool (Fig. 4).

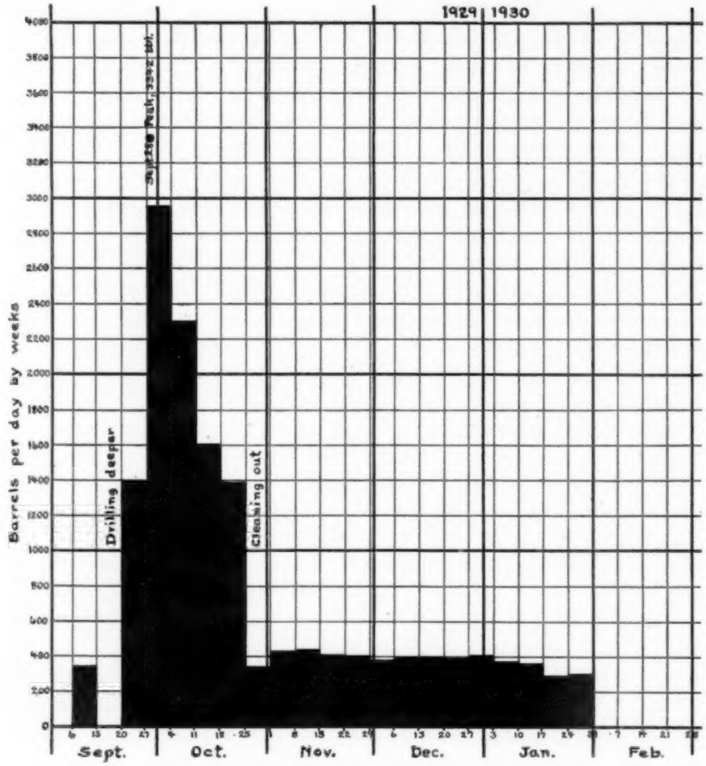


FIG. 3.—Standard Oil Company of Louisiana's Caddo Parish School Board well No. 1; graph showing average daily production by weeks.

These curves show clearly that the larger flowing wells decline rapidly in production for about a month, but after pumping is begun the decline is slow, and the wells should have long life as pumpers, similar to wells in the older parts of the Caddo field.

The proved area of the pool may be considered to be 370 acres, or 10 acres for each producing well up to January 1, 1930. On this acreage, the production during the first 8 months was 1,590 barrels per acre, which is probably a little less than half of the total ultimate recovery to be expected from these wells.

It is not yet possible to make any close estimate on the ultimate total recovery for the entire pool, as this depends largely on future drilling.

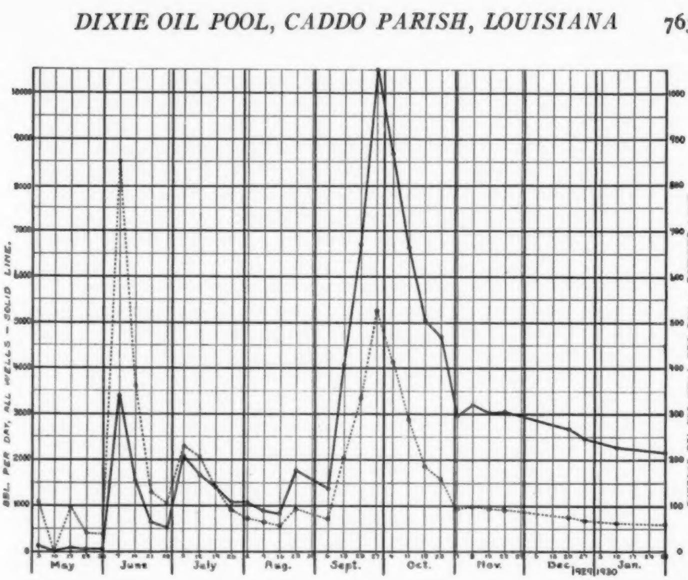


FIG. 4.—Dixie oil pool; curve showing total daily production and average daily production per well.

There are several hundred acres adjacent to production and not yet condemned as a result of drilling, which may or may not include other small sand lenses where groups of exceptionally large wells will be obtained. However, it is not to be expected that any wells in the Dixie area will be as large as some in the western part of the Caddo field, where, for example, the Standard Oil Company of Louisiana's Stiles No. 58, in the Trees City district, was completed in January, 1913, pumping 100 barrels per day, increased to 500 barrels per day, and up to January 1, 1930, had produced more than 1,840,000 barrels; and the Gulf Refining Company's Ferry Lake No. 215, near Mooringsport, completed in April, 1924, flowed 1,155,720 barrels in 641 days, then was put on the pump and had produced 1,319,000 barrels up to January 1, 1930. Such wells on the west flank of the uplift produce wholly or in part from the Lower Cretaceous, probably from faults or inclined sand beds in the Washita formation, as is shown by the fact that some wells in the Trees City area have made producers with casing set below the base of the Tokio formation. As previously mentioned, the present evidence indicates that the upper part of the Lower Cretaceous beds will not be commercially productive in the Dixie area.

ANCESTRAL ROCKY MOUNTAINS[1]

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Wichita, Kansas

ABSTRACT

The probable location of the "Ancestral Rocky Mountains" was first described by Willis T. Lee in 1918. Inasmuch as he failed to delineate their areal extent, subsequent references and maps have differed in regard to the location of these mythical mountains. The writer has brought together all the evidence which bears on the problem. He has prepared isopach maps of the Cordilleran basin in order to show the probable source of sediments during the Mississippian, Pennsylvanian, and Permian periods. On these maps he shows the areas where clastics make up the total or a large part of the stratigraphic section for these systems, again showing the probable source of sediments or the close proximity of land.

The evidence tends to prove that the Ancestral Rockies probably began their history in Proterozoic time; that they were rejuvenated at the close of Ordovician time, and again at the close of Mississippian time. The Ancestral Rockies of Lee, however, began their history in middle Pennsylvanian time and probably constituted a range quite as high as the present mountains. The evidence shows that the following tectonic elements were the framework of the Ancestral Rockies: Uinta-Front Range element; Uncompahgre-Sangre de Cristo element; Defiance-Zuñi element; Pedernal-Mesa de Maya element; and Amarillo-Wichita element. Each is described as to location, height, source of sediments, and geologic history.

The first description in the literature of the Ancestral Rocky Mountains is to be found in the *Smithsonian Miscellaneous Collections*, Volume 69 (1918). In an article entitled "Early Mesozoic Physiography of the Southern Rocky Mountains," Willis T. Lee proposed this name for a buried mountain range located in the western part of the High Plains. In a paper read before the Geological Society of America in December, 1922, Lee describes the location and character of these mythical mountains more fully. The writer will therefore quote a few sentences from that paper in order to show exactly what Lee intended to convey to his fellow geologists. He says, "In late Carboniferous time mountains which have been called the Ancestral Rockies, comparable in size to the present Rocky Mountains, occupied the site of the Southern Rockies, and sediments were shed from them in all directions."

In the illustration which accompanies Lee's paper, he shows first the profile of the United States along the 39th parallel (which passes

[1]Read by title before the Association at the New Orleans meeting, March 22, 1930. Manuscript received by the editor, February 27, 1930.

[2]The Municipal University of Wichita.

between Denver and Colorado Springs), noting especially the Great Basin, the Wasatch Mountains, the High Plateaus, the Southern Rockies, the foothills, and the Kansas-Colorado boundary line. In the second part of the illustration he shows the Ancestral Rockies directly on the site of the present Front Range of Colorado, with seas stretching away on both sides to the limits of the previous profile. Succeeding parts of the illustration (*C*, *D*, *E*, *F*, *G*) show the reduction of the Ancestral Rockies to a peneplain; their submergence below sea-level; deposition of sediments during Cretaceous time; and the structural relationships at the present time. In other words, both Lee's description and his illustrations show clearly that he wished to place the Ancestral Rockies exactly on the site of the present Front Range of the Rocky Mountains in Colorado.

Several references and brief descriptions have appeared since Lee last described the Ancestral Rockies, but the most complete statement of the problem and the most searching analysis of the data we owe to Melton.[1] Considering the fact that our data and our general knowledge of the region involved have been multiplied greatly since 1925, the reader will find, after an examination of Melton's map, that he was quite correct in his interpretation of the facts. The present writer, therefore, is merely adding a few details and building up on what has gone before.

JUSTIFICATION OF LEE'S ANCESTRAL ROCKIES

The question naturally arises in the mind of every geologist, "What was the justification for assuming that a range of mountains existed on the site described by Lee?" From his writings it is clear that Lee had in mind three lines of evidence. The first of these, and the one that probably prompted an investigation of the problem, is the character of the materials which make up the Pennsylvanian, Permian, and Triassic rocks. The second is the change in thickness of the same strata throughout the middle of the Cordilleran basin. The third is the surface and subsurface distribution of the strata involved.

At the time Lee first suggested the existence of the Ancestral Rockies, much information regarding the Carboniferous and early Mesozoic rocks in Colorado and adjacent states was available. This applies particularly to the outcrops and the subsurface information obtained from mines. Since 1923 the widespread search for petroleum, guided and interpreted by many zealous geologists, has provided much additional information. With all the facts and data available at the present moment plotted on a map of the western part of the United States, the result appears as shown in Figure 1.

[1] F. A. Melton, *Jour. Geol.*, Vol. 33 (1925), pp. 84-90.

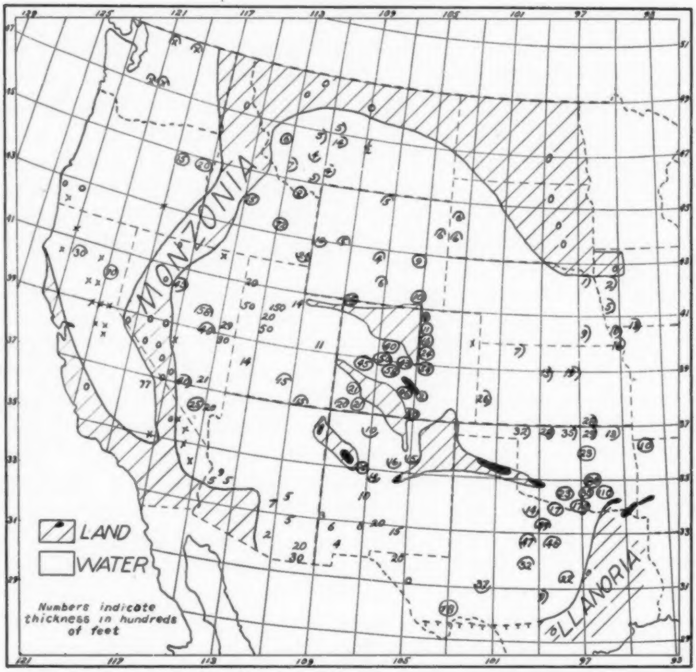


FIG. 1.—Map of the Cordilleran basin showing the location of the Ancestral Rocky Mountains. The thickness of the Pennsylvanian rocks is shown in hundreds of feet. A circle around the number indicates that the sediments are all clastic; proportional amounts are indicated by proportional parts of the circle; a cross indicates that the Pennsylvanian rocks are present, but the thickness is not known.

LOCATION AND TECTONIC SETTING

The evidence seems to indicate that the Ancestral Rockies were located in northwestern, central, and southwestern Colorado, and that elevated tracts of land existed synchronously in northwestern New Mexico, northeastern New Mexico, the Panhandle of Texas, and southwestern Oklahoma. The map also shows that these land areas were islands in a rather extensive sea whose boundaries were far removed on every side. The continental segment, Monzonia, so called because it consists mostly of monzonite and related types of igneous rock, formed the western border of the Cordilleran basin, while on the northwest lay Laurentia, on the east Ozarkia, and on the southeast Llanoria.

FRAMEWORK

The component elements of the Ancestral Rocky Mountains are tectonic units which have had a rather long, and most of them a rather complex, geologic history. Probably all of them came into being during, or even before, Proterozoic time. Some of them seem to have suffered repeated rejuvenations; others do not show the evidence of such changes. In order from the northwest, they may be termed the Uinta-Front Range element, the Uncompahgre-Sangre de Cristo element, the Defiance-Zuñi element, the Pedernal-Mesa de Maya element, and the Amarillo-Wichita element.

UINTA-FRONT RANGE ELEMENT

The *Uinta element* is a tectonic element with predominant trend from west to east, which begins east of Salt Lake City and extends into northwestern Colorado. Its probable western continuation in pre-Cambrian time is clearly indicated by a conspicuous amount of pre-Cambrian rock in some of the desert ranges west and southwest of Utah Lake, in Utah. The eastward-pitching Bingham-Park City anticline, and the Deep Creek-Tintic uplift (which suffered a seeming displacement toward the south as a result of the late Cretaceous faulting) are on the trend of the Uinta arch. The Wasatch range, which now separates the Uinta arch from its former western continuation, was probably formed by overthrust faults in late Cretaceous or early Tertiary time.[1] These faults and the synchronous folds have greatly obscured earlier deformations. The evidence for such earlier diastrophic movements is, therefore, meager and speculative. Nevertheless, there are some indications of diastrophism at the close of the Ordovician period and again at the close of the Mississippian period. On the main part of the Uinta arch only Proterozoic rocks are now exposed ("Uinta group"). These are overlain on the flanks by thin sediments of unknown age, the Lodore formation. Ordovician rocks were reported by Weed on the south flank. On the other three flanks, however, the oldest sediments are of Mississippian age and are separated from the underlying rocks by an angular unconformity. This record indicates diastrophism and probably widespread erosion after Ordovician time. In the Cottonwood-Park City area west of the arch, the angular unconformity between the Mississippian limestone and the underlying Cambrian is pronounced.[2] The next period of uplift and erosion is indicated by the widespread appearance of clastic

[1] B. S. Butler, *U. S. Geol. Survey Prof. Paper 111* (1920). p. 102.

[2] *Ibid.*, p. 233.

sediments in the Pennsylvanian section around the periphery of the Uinta arch. This diastrophic movement probably took place at the close of the Mississippian period. The ancient quartzite core of the mountains furnished the sediments for the Weber and related formations.

The continuation of the Uinta element toward the east is obscured by a blanket of Cretaceous and Tertiary rocks. The "windows" of older rocks which appear in Juniper and Cross Mountains make it possible to follow the axis nearly to a point southwest of Craig in Moffat County, northwestern Colorado. If projected from that point toward the southeast past Glenwood Springs, it seems to find its further continuation in the Sawatch anticline, which lies between Aspen and Leadville. With only slight interruptions, it may be further projected into the Wet Mountains and the Apishapa arch.

The *Front Range element* is a tectonic element trending nearly north and south between the meridians of 105° and 106° longitude. In its present condition it is separated from the Park Range element by the North Park basin. Formerly these two elements were united, thus forming a unit reaching as far west as longitude 107°. This larger unit is triangular in shape and comes to a point between Colorado Springs and Canyon City.[1] Its further continuation is obscured by Cretaceous and younger deposits, but may be traced southeastward past Pueblo for a short distance.[2]

That this element has been a positive element since Proterozoic time is indicated by the stratigraphic record in North Park, especially, and, to a certain extent, east of the present Front Range. In all probability it remained a land mass throughout Cambrian, Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian time. For that reason, diastrophism during early Paleozoic time is difficult to decipher. Yet the fact that clastic sediments were laid down at the south end during late Ordovician time (Harding) indicates crustal movements at that time. This is confirmed by the fact that an angular unconformity appears above the Ordovician rocks in the northern part of Garden Park (north of Canyon City). At some time between the close of the Ordovician period and the middle of the Pennsylvanian period, there must have been diastrophism followed by erosion.

Along the east side of the Front Range, from Morrison northward as far as Douglas, Wyoming, the Fountain formation or its equivalent lies directly on the granite and no trace of older Paleozoic formations

[1] *U. S. Geol. Survey Prof. Paper 148*, Pl. 33.

[2] N. H. Darton, map in *U. S. Geol. Survey Bull. 691*, Pl. 1.

has been discovered. In North Park, the oldest formation above the pre-Cambrian is the Permian (Forelle) limestone.

UNCOMPAHGRE-SANGRE DE CRISTO ELEMENT

The *Uncompahgre tectonic element* may be traced from a point in western Colorado between the Grand and Dolores rivers (about 39° latitude and 109° longitude). Pre-Cambrian granites, gneisses, and schists appear in a relatively small area. They are overlain by Jurassic (Wingate) sandstones, although there is possibly some Triassic (Chinle) present locally. These formations are described under the name of Dolores by Coffin.[1] Farther southeast along the trend of the Uncompahgre element, Tertiary volcanics obscure the stratigraphic sequence to a large extent. In the Needle Mountains quadrangle, some information regarding the nature and trend of the ancient land mass is presented in the form of a northwest-southeast trending synclinorium of Algonkian rocks. Pre-Cambrian rocks also appear west of Conejos and south of San Luis.

This land mass furnished sediments for the Ignacio sandstones of southwestern Colorado during Cambrian time; formed part of a much larger land mass during Ordovician and Silurian time; and again furnished sediment for the Elbert formation of southwestern Colorado during Devonian time. In late Devonian and Mississippian time it was very low-lying land. The first definite evidence of diastrophism and rejuvenation appears in the coarse clastic sediments of Pennsylvanian time. These are now to be seen both on the north and on the south side of the old land mass.

The *Sangre de Cristo* element is a tectonic element which trends nearly north and south about longitude 105°30′. It extends from north-central Colorado southward into north-central New Mexico. The stratigraphic record indicates that it was a positive element and a land mass from pre-Cambrian time until the middle of the Pennsylvanian period or later, for the oldest rocks that are now found on its flanks are Pennsylvanian sediments. In Colorado and in northernmost New Mexico they are coarse clastics, but farther south, limestone appears in the section.

DEFIANCE-ZUÑI ELEMENT

The *Defiance element* lies in northeastern Arizona. Little is known regarding its trend or its extent because it is almost completely buried under Permian strata. Three miles northwest of Fort Defiance the pre-Cambrian may be seen at the surface. There the Coconino

[1] R. Clare Coffin, *Colorado Geol. Survey Bull. 16* (1921), pp. 56-60.

sandstone overlaps onto the old rock with pronounced unconformity. Darton[1] reports that knobs of the old pre-Cambrian surface 50 feet high were noticed. In most places sandy shale lies against the old rock, but locally angular masses of quartzite form coarse basal conglomerate.

The *Zuñi element* lies in northwestern New Mexico, trends northwest, and is bounded approximately by the parallels of 35° and 36° latitude and the meridians of 107° and 109° longitude. The fact that here also the Permian (Abo) sandstone directly overlies the pre-Cambrian granite indicates that the Zuñi element has had a history similar to that of the Defiance uplift, and was a land mass throughout the Paleozoic era up to (and perhaps well into) the Permian period. The fact that clastic Pennsylvanian sediments appear northeast, northwest, and southeast of the Defiance-Zuñi element makes it evident that this positive element had a trend from northwest to southeast, as indicated on the map.

PEDERNAL-MESA DE MAYA ELEMENT

The *Pedernal-Mesa de Maya element* lies in northeastern New Mexico and by means of the stratigraphic record can be traced from a point in Colorado (37°30′ lat., 103° long.) near Troy, in a southwesterly direction to the Pedernal uplift (34°45′ lat., 105°40′ long.). The character and general extent of the Mesa de Maya structure may be ascertained from an inspection of Darton's maps.[2] The second map also shows the Pedernal Mountain as well as the configuration of the bed rock in northeastern New Mexico. Many wells have been drilled in the search for oil within this area, and, as far as may be determined from the cuttings, all passed from Permian sandstones into pre-Cambrian rocks or arkose. The assumption therefore seems to be warranted that this element was a positive element and a land mass from pre-Cambrian time well into Permian time.

AMARILLO-WICHITA ELEMENT

The search for oil has also revealed another positive tectonic element in the northern part of the Texas Panhandle. This buried mountain ridge extends from latitude 35°30′ to 35°45′ and from longitude 100°30′ to 102°. It has been named the Amarillo Mountains by Gould and this name is now in general use. Along the same trend, but farther east,

[1] N. H. Darton, *Arizona Bur. Min. and Eng. Bull. 119*, p. 86.

[2] N. H. Darton, *U. S. Geol. Survey Bull. 691*, Pl. 1, and *Bull. 794*, Pl. 60.

lies the Wichita Mountain range of southwestern Oklahoma. Here the pre-Cambrian rocks come to the surface and are exposed in an area which centers about the intersection of the parallel of 39° latitude and the meridian of 99° longitude. These two ancient tectonic elements are presumably connected, although not enough drilling in the intervening area has been done to establish this conclusion as a fact. The stratigraphic record indicates that the Amarillo element functioned as a positive element from pre-Cambrian time to about the close of Pennsylvanian time. The Wichita element was submerged in late Cambrian and throughout most of Ordovician time, but became a land mass after Ordovician time and remained land thereafter. The narrowness of this element and its western continuation makes it appear that faulting has controlled its origin, rejuvenation, and areal extent. The finding of the Bravo dome (35°40′ lat., 103° long.), near the boundary between Texas and New Mexico, establishes a connection between the Pedernal-Mesa de Maya element and the Amarillo element.

WET MOUNTAINS AND APISHAPA ARCH

A rather small tectonic element which may be independent, or may be a continuation of the Sawatch Mountain element, consists of the present Wet Mountain salient and the buried extension called the Apishapa arch. The Sawatch Range begins in central Colorado east of Glenwood Springs, about latitude 39°30′ and longitude 106°30′. It trends southeasterly between Aspen and Leadville as far as latitude 38°30′ and longitude 106°. The Wet Mountains begin on the same trend a short distance farther southeast and extend a little beyond the intersection of the parallel of 38° latitude and the meridian of 105° longitude. In the Walsenburg folio this blunt end of the Wet Mountains is called the Greenhorn Mountains.

The Apishapa arch appears to be a structural continuation of the Greenhorn Mountains. It has been mapped in the United States Geological Survey folios of the Walsenburg and Apishapa quadrangles. Darton also shows its position and extent by means of structure contours on the Dakota sandstone.[1] This shows that the structural feature extends as far as latitude 37°30′ and longitude 104°, where it joins the Mesa de Maya dome. As no deep wells have been drilled on the Apishapa arch, our information concerning the stratigraphy is very meager. Therefore, it is impossible to say at the present time what relation the different

[1] N. H. Darton, *U. S. Geol. Survey Bull. 691*, Pl. 1.

structural elements have to each other or what their age may be. Presumably the Apishapa arch is a Cretaceous feature.

Regarding the Wet Mountains, the stratigraphic record shows that they constituted a positive tectonic element in Pennsylvanian time and probably existed as a land mass continuously since pre-Cambrian time. The coarse clastic materials of Pennsylvanian age appear only on the southeast side and are only 200 feet thick. Hills applied the name *Badito* to the formation. The comparatively slight thickness of the Badito indicates that the Wet Mountain element was not a high land mass in Pennsylvanian time.

OTHER TECTONIC ELEMENTS

A study of the map shown as Figure 1 indicates that only the positive elements mentioned and described in the preceding pages were land masses throughout the Pennsylvanian period. Other elements were present in the Cordilleran basin which were land masses during a part of Pennsylvanian time. Some of these are shown on the map of Mississippian land and water conditions (Fig. 2).

One of the most interesting tectonic elements shown on this map is the *Red River uplift* in north-central Texas. The records of many wells indicate a ridge or rather a series of ridges of granite and Ordovician limestone with an east-west elongation, stretching from longitude 100° to 97° and lying between parallels 33°30′ and 34°15′ latitude. This tectonic element was formed at the close or during the latter part of the Ordovician period, and remained a land mass until middle Pennsylvanian time (Canyon). This is indicated by the overlap relations between the Canyon sediments and the Ellenburger limestone of middle Ordovician age.

The Nemaha Mountain range (and its extensions), reaching from Nehawka, Nebraska (41° lat., 96° long.) through Kansas and north-central Oklahoma well beyond Oklahoma City, seems to have been a land mass during earliest Pennsylvanian time only (Bendian and Pottsville). Many well records indicate that the Mississippian limestone was laid down over it and removed during late Mississippian (Chester) and early Pennsylvanian time. In a general way we may date its submergence as of middle Pennsylvanian time (Marmaton and latest Cherokee). The pre-Mississippian history of this element is not clear as yet. The writer believes that it experienced its first uplift by faulting during or at the close of the Ordovician. Most petroleum geologists, however, do

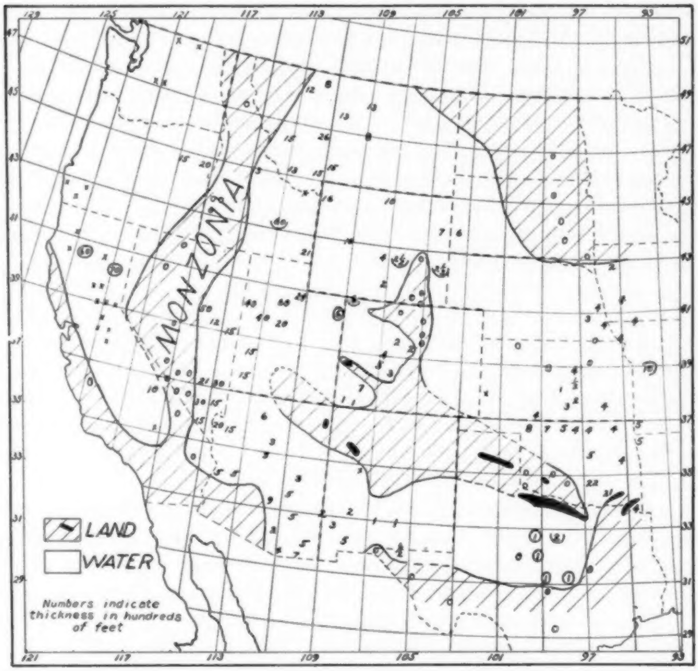


FIG. 2.—Map of the Cordilleran basin showing the foundation for the Ancestral Rocky Mountains and the thickness of the Mississippian strata throughout the depositional basin. Numerals indicate the thickness in hundreds of feet. Part of circle around the numerals indicates proportional amount of clastic materials.

not agree with this view and are inclined to look upon the post-Mississippian disturbance as the first major uplift.

The *Barton arch* in west-central and northwestern Kansas seems to have been a land mass from middle Ordovician time until well into the Pennsylvanian. Indeed, on its projected trend in Nebraska, even the Pennsylvanian is missing and Permian rocks rest directly on the Arbuckle limestone. The record of a well in eastern Decatur County which shows only 640 feet of Pennsylvanian rocks above the pre-Cambrian seems to indicate that parts of this area remained land until late in Pennsylvanian time. This well is located on the flanks of a long anticline extending from the direction of the Black Hills, which has been

called the *Cambridge anticline*.[1] The reciprocal age and structural relations of the Barton arch and the Cambridge anticline are not known at present.

Perhaps the most interesting tectonic elements shown on the map are the *island festoons* of the old continent of Llanoria. Plentiful evidence of the metamorphosed sediments of this continental mass is found in wells drilled east of the Balcones fault. In that way its eastern edge may be defined from the village of Rockwall (northeast of Dallas) southward through eastern McLennan County, et cetera. [2] If the Balcones fault line is projected northward along the same trend (instead of being projected eastward at right angles, as is commonly done on maps), it will be seen that the fault line emerges from under the Cretaceous and Tertiary cover, to connect with a narrow zone of ancient rocks. These ancient rocks are mainly cherty limestones of Ordovician (Bigfork) and Mississippian (Woodford) age and crop out east of Atoka in a narrow strip and along the Ti Valley fault in small areas toward the northeast. A somewhat larger area lies slightly south of this trend on the line between Latimer and Pushmataha counties and has been called the *Potato Hills uplift*.

That these islands of older rocks existed in early and middle Pennsylvanian time is fully attested by the erosional detritus derived from them. Taff reports, for example, that cherty conglomerates appear throughout a thickness of 3,000 feet of Pennsylvanian strata in the Lehigh basin on the northwest. Other geologists have found boulders and cherty conglomerates of similar lithologic materials down to the very base of the Pennsylvanian (Wapanucka) in adjacent areas. A wave-sorted residual soil consisting of chert pebble conglomerate rests upon the older rocks in the Potato Hills.[3]

Of greater importance than the island festoon is the *Choctaw tectonic element* which has been accurately portrayed on a map by Honess.[4] This element is buried throughout most of its extent by the delta deposits of earliest Pennsylvanian time (Stanley and Jackfork). It protrudes from this cover in central McCurtain County, Oklahoma (T. 5 S., R. 24 E.), where it has a northeasterly trend. It appears in the heart of

[1] *Op. cit.*

[2] M. G. Cheney, "Stratigraphical and Structural Studies in North Central Texas," *Univ. of Texas Bull. 2913* (1929).

[3] For additional details see Sidney Powers, *Geol. Soc. Amer. Bull. 39*, pp. 1036-49, especially map on p. 1038.

[4] Charles W. Honess, *Oklahoma Geol. Survey Bull. 32*, Pl. 1.

the Cross Mountains, and similarly in the Crystal Mountains, whence it may be projected to the Hot Springs district.[1]

The stratigraphic relations of these areas are difficult to decipher. Therefore, the geologic history of the Choctaw element is not well known. Honess and Miser have done much work on this problem. The facts accumulated and published by them permit the following conclusions to be drawn. The Choctaw element consists chiefly of black shales, some limestone, and much sandstone (Collier and Crystal Mountain formations). All of the sediments have been so greatly changed by repeated metamorphism that it is practically impossible to determine structural relations. Inasmuch as the strata do not contain fossils, it is not possible to assign them definitely to a position in the stratigraphic column. As they occur below rocks of undoubted Ordovician age (Beekmantown), they have been tentatively placed in the Cambrian and Ordovician systems. In the light of their tectonic relations it seems entirely possible that they may be of Proterozoic age. If so, they would be of the same age as the materials found in the wells east of the Balcones fault. If this assumption proves to be correct, we have in the Choctaw element a part of the old continent of Llanoria that is not obscured by a cover of younger rocks.

Inasmuch as the Mazarn and Blakely formations are missing on the flanks of the Choctaw arch in McCurtain County, it seems that this tectonic element was a land mass until Trenton time at least, and may have continued to supply sediments until early Pennsylvanian time. Honess states that he placed a fault on the east flank "with some hesitancy" because of the fact that three formations are missing there. On the east flank, where the same is true, he did not show a fault. It seems probable, therefore, that the Womble(?) sandstone overlaps onto the Choctaw arch. The Womble of Honess is probably the equivalent of the Simpson formation, since the overlying Bigfork is equivalent to the Viola. Therefore, if we wish to reach some conclusion as to the age of the diastrophic movement that caused the Choctaw arch, the best we can do at present is to call it pre-Simpson.

In Arkansas we have more data, because fossils have been found as low in the section as the Mazarn shale. Miser's splendid work extending through a period of many years has given us ample field observations which make certain conclusions possible. Nevertheless, the earliest point of time that can be discerned in the stratigraphic record for diastrophic movements is the close of the Ordovician period. This is in-

[1]See map in H. D. Miser's report on the structure of the Ouachita Mountains in *Oklahoma Geol. Survey Bull. 50* (1929). Also see *U. S. Geol. Survey Bull. 808*.

dicated by the clastic nature of the Blaylock sandstone (Silurian) and its great variation in thickness. Miser reports that at one place in the Caddo Gap quadrangle he found a difference of 1,500 feet in 3 miles. He also reports the fact that the Bigfork chert (Viola) is much more severely distorted by diastrophism than the very similar Arkansas novaculite (Woodford).[1] Farther east in the Hot Springs district Miser reports that wherever the Hot Springs sandstone is present there is not only a basal (Pennsylvanian?) conglomerate, but all intervening strata are missing down to the Bigfork chert.[2] Of course, it is possible that this evidence might be construed as indicating post-Woodford diastrophism.

The upper part of the Arkansas novaculite is generally admitted to be the equivalent of the Woodford. If the Woodford is considered to be of Mississippian age, we may date the second period of diastrophism as post-Mississippian or late Mississippian. This effected a rejuvenation along the old lines in the Choctaw element and probably produced the island festoon farther northwest; for in the islands there is a hiatus between the Woodford (or its equivalent) and the overlying basal conglomerates of the Stanley. If the Stanley is a very early Pennsylvanian deposit (Bendian), as now seems indicated by much evidence,[3] the time of this diastrophism agrees remarkably well with evidence found elsewhere in the Cordilleran basin. Unfortunately, the fact that the thick deposits of shale and sand, which now constitute the Stanley and Jackfork, were spread out over the land masses, has served to obscure pre-Pennsylvanian structure. To make matters worse, very violent diastrophism during Pennsylvanian time affected these same strata and all older strata in such a pronounced manner that previous structural relations are almost eliminated.

LOCATION OF ANCESTRAL ROCKY MOUNTAINS

The areas which were probably land during all of Pennsylvanian time are shown on the map (Fig. 1). These areas are not all mountainous and, moreover, none of them was mountainous in early Pennsylvanian time. If we wish to restrict the term "Ancestral Rockies" to those areas which were mountainous, we should include only the Uinta-Front Range and Uncompahgre-Sangre de Cristo elements. These elements were high during middle and late Pennsylvanian time.

[1]Hugh D. Miser, *U. S. Geol. Survey Bull. 808*, p. 36.

[2]Hugh D. Miser, *Oklahoma Geol. Survey Bull. 50*, p. 26.

[3]Micro-fossils of pre-Pottsville, post-Chester age, et cetera.

The evidence for these statements is to be sought in the stratigraphic record.

DISTRIBUTION OF CLASTICS

Materials of a very coarse nature, including conglomerates and arkoses, are found especially in central Colorado on the east side of the Front Range, between the two northern elements, in front of the Sangre de Cristo element, and in southwestern Colorado southwest of the Uncompahgre element. They constitute the Fountain formation, the Sangre de Cristo formation, the Maroon conglomerates, part of the Weber grits, the Kangaroo formation, and part of the Hermosa formation. The Fountain is perhaps the most typical and best known of the formations mentioned. It is found on the east side of the present Front Range from Colorado Springs north into Wyoming.[1] It consists of slightly disintegrated detritus from granitic rocks, that is, arkoses, grits, sandstones, and conglomerates. Red colors predominate, as would be expected where residual materials, mechanically derived from granite, are suddenly dumped into an adjacent sea by rejuvenated streams.

The Maroon and related formations (Weber partly, Kangaroo, Wyoming, et cetera) are found between the two northern elements. They have been described in the Red Cliff, Tenmile, Breckenridge, Leadville, Alma, Aspen, Grand Mesa, Crested Butte, Gold Brick, and Monarch mining districts.[2] In general, they consist of very coarse conglomerates and arkoses with predominant red colors. Where the color is not red, there seems to be a tendency to call them Weber grit. In many places large boulders, many feet in diameter, are reported as forming part of the sediments. This, as well as the angularity of the material, indicates near-by land. At Ouray the Hermosa formation consists of coarse conglomerate (quartzite and chert pebbles) at the base, with massive, coarse, and gritty sandstones making up the overlying part. Farther away from the land mass (southwest), shales and thin limestones appear in the section. At three places on the eastern front of the Sangre de Cristo element, similar materials have been described. Melton described the very thick clastic section near Crestone and Salida. Lee described the equally thick section on the south fork of the Purgatoire River, and Hills described the Badito formation in the Walsenburg quadrangle.[3] Farther south, in New Mexico (near Las

[1] Willis T. Lee, *U. S. Geol. Survey Prof. Paper 149.*

[2] *U. S. Geol. Survey Prof. Paper 148, Colorado State Survey reports 4* and *10*, and *U. S. Geol. Survey Prof. Paper 16.*

[3] F. A. Melton, *Jour. Geol., op. cit.*, p. 810. See also George H. Girty in *U. S. Geol. Survey Prof. Paper 16*, pp. 89-96; Willis T. Lee, *U. S. Geol. Survey Prof. Paper 101*, p. 40; and R. C. Hills, *U. S. Geol. Survey Atlas Folio 68.*

Vegas and Glorieta Mesa), Lee reports angular pieces of granite and feldspar near the top of the Magdalena. Similar breccia conglomerate appears in the overlying Permian (Abo) sandstone, which, incidentally, is separated from the Magdalena by an angular unconformity. These facts make it seem probable that the Ancestral Rockies extended as far south as latitude 34°30′. Because of the fact that the Magdalena is found north of this, the writer has preferred not to extend the Sangre de Cristo element as far as this on the map.

Somewhat different conditions seem to prevail adjacent to the Uinta element in southern Wyoming and northeastern Utah. There the Pennsylvanian strata consist mostly of gray, cross-bedded sandstone, and are commonly referred to the Weber formation. In southeastern Wyoming, north of the Front Range element, similar materials are called the Casper formation. The presence of some limestone and shale in the section indicates that the land which furnished these sediments was not very high.

On the borders of the other tectonic elements described, we find evidence of a certain amount of arkosic materials in the record. For example, along the north side of the Amarillo Mountains, such material has been encountered in many wells. Fossils have been found in it which show that it was accumulated in sea water during late Pennsylvanian time (Waubaunsee, Douglas, Shawnee). Still farther east, coarse sediments of similar age have been found in large quantities and throughout a considerable area. These are referred to the Pontotoc formation and have been found as far east as the north side of the Arbuckle Mountains.

VARIATION IN THICKNESS

Near a high land mass, a greater thickness of strata is to be expected than farther away. It is therefore interesting to examine the isopach map of the Pennsylvanian system, to see where the greatest thicknesses of sediment were laid down. Seven areas of excessively thick deposits may be noticed. The westernmost area lies in central Nevada; another, in southeastern Idaho. The thickest section appears in the Ardmore basin of southern Oklahoma, where clastics reach a total thickness of more than 17,000 feet. A great thickness is reported from southeastern Oklahoma, but because of faulting it is difficult to arrive at the correct figures and the estimates are probably too large.

The three areas which are of the greatest interest in the present study lie in central Colorado. They lie northeast and east of the Sangre de Cristo element. Melton reports a thickness of 13,000 feet of coarse clas-

tics near Crestone, subdividing it into 7,500 feet of Pennsylvanian and 5,500 feet of Permian. He states that the Pennsylvanian part is composed of finer conglomerate and arkose than the Permian part, and that it has a darker red color. The Permian part contains boulders as large as 8 feet in diameter.

On the south fork of Purgatoire River, west of Trinidad, Lee measured a section possibly 14,000 feet thick, of which he assigns 9,000 feet to the Pennsylvanian and 5,000 feet to the Permian. Red sandstones, grits, and conglomerates characterize the whole thickness, although some red shale is noted. He states that the conglomerates appear from top to bottom in the section and that some of them contain very large boulders.

Along the east side of the Front Range element, the Fountain formation ranges in thickness from 700 feet at the north end (in Wyoming) to 5,400 feet at the south end (west of Colorado Springs). Lee described the deposits at closely spaced intervals along the mountain front. He states that the Fountain formation consists chiefly of arkose, red sandstone, grit, and conglomerate; that it is coarse-grained, crumbling, and mottled with gray and light shades of red; that it is very irregularly bedded, suggesting accumulation in stream channels and similar environment.

A description of this nature would also fit the Pennsylvanian sediments which lie between the Uinta-Front Range element and the Uncompahgre-Sangre de Cristo element; for, in the Red Cliff mining district (north of Leadville), 4,000 feet are reported; the same amount in the Tenmile district; 1,000 feet in the Breckenridge district; 1,000 feet in the Leadville district; 2,500 feet in the Alma district; 4,000 feet of the Maroon formation and 1,000 feet of the Weber formation in the Aspen district; 4,500 feet of conglomerate and red beds in the Grand Mesa district; 4,500 feet of Maroon conglomerate and sandstone in the Crested Butte district; and 3,000 feet of Kangaroo quartzite, conglomerate, and shale in the Monarch district.

In southwestern Colorado the period of time during which such coarse materials were laid down extends from middle Pennsylvanian through the Permian and well into the Triassic period. The Hermosa formation (2,000 feet) and the Cutler formation (2,000 feet) are both characterized by coarse sediments. Cross[1] reports several very coarse, massive conglomerates in the upper part of the Cutler. Farther northwest along the Uncompahgre element, Coffin[2] reports boulders

[1]Whitman Cross, *U. S. Geol. Survey Atlas Folio 153*. (Revised nomenclature in *Prof. Paper 150*, p. 77.)

[2]R. Clare Coffin, *Colorado Geol. Survey Bull. 16*, p. 58.

1½ feet in diameter in the conglomerate and arkose of the Cutler formation.

TIME OF UPLIFT

After having reviewed the evidence in favor of the theory that high land masses existed in Pennsylvanian time, it becomes interesting to inquire whether the time of uplift can be determined; and, if so, whether it corresponds with crustal disturbances observed elsewhere. The coarse materials which make up the Fountain and related rocks rarely contain fossils. A few were found by Finlay 400 feet above the base, and he also reports the finding of similar fossils in northern Colorado. These indicate merely a Pennsylvanian age for the formation, but do not make possible a closer determination. Some help is obtained from the fossils in the Glen Eyrie formation, which underlies the Fountain at the southern end of the outcrop. The plant fossils found in it were identified by White, who believes that they indicate an upper Pottsville age for the Glen Eyrie formation.

Rocks which are similar, lithologically, to the Glen Eyrie are reported from the Tenmile district (300 feet of lower Weber black shale); from the Alma district (300 feet of lower Weber shale); from the Aspen district (1,000 feet of carbonaceous limestone and shale); from the Crested Butte district (500 feet of Weber shale, sandstone, and limestone); from the Gold Brick district (300 feet of limestone and shale); from the Monarch district (2,800 feet of Garfield black shale, et cetera); from the Crestone region (2,100 feet of black shale and limestone).

In southwestern Colorado the Molas formation seems to occupy the same time interval. There it is a typical residual limestone soil which has become submerged by rising sea water; for it consists of chert fragments enclosed in a red marly matrix. In some places it appears as a limestone and chert breccia with the same red marly matrix. It is reported in the Ouray, Silverton, Needle Mountain, Engineer Mountain, and Rico quadrangles. The thickness ranges from almost nothing to about 75 feet. The lower part of the Hermosa also indicates quiet conditions of deposition, and indeed has been assigned by Girty to the lower Pennsylvanian.

In southwestern Colorado we probably have the best evidence in the stratigraphic record for determining the point in time when the Ancestral Rockies (of Lee) were produced. In the Engineer Mountain quadrangle, the upper third of the Hermosa consists of massive grits (300 feet), which are feldspathic and pink, but the middle part is characterized by limestone. The lithologic record, therefore, shows

the birth of the mountains between middle and upper Hermosa time. The Rico (thought to be of Permian age) consists of feldspathic sandstone which is red and cross-bedded. The next higher formation, the Cutler, also contains mostly sandstones and grits which are highly feldspathic. The pebbles in the conglomerates are derived, for the most part, from pre-Cambrian rocks. This fact, as well as the abrupt changes in thickness and lithology, indicates a land mass near by.

According to Girty the Hermosa is "probably older than the Upper Coal Measures faunas of the Kansas and Nebraska sections." Accordingly, we are not able to fix the time of the Ancestral Rocky Mountain uplift closer than about middle Pennsylvanian time. This, however, is in close agreement with the findings of workers in other parts of the Cordilleran basin, indicating that the middle of the Pennsylvanian period was a time of violent deformation. In southern Oklahoma, for instance, Tomlinson, in his masterful study of the Glenn formation of the Ardmore basin, finds that the first manifestations of an impending revolution appear in middle Deese time.[1] Renewed movements are indicated by the coarse materials in the Hoxbar formation, although the great angular unconformity, as well as the lithology of the Pontotoc, indicates that the most violent movements took place at that time.

It is interesting to notice, from Dott's[2] and Gouin's[3] work, that the characteristic lithology of the Pontotoc may be traced toward the west through Garvin, Stephens, and Comanche counties, into Beckham County, on the west line of the state. There Gouin correlates it with the arkosic materials found in wells of the Amarillo district (called granite wash there), thus making possible a further correlation with similar materials found in wells drilled on the north end of the Mesa de Maya element. From that area it is only a short step to connect the Pontotoc with the Fountain in its typical environment.

PERMIAN ANCESTRAL ROCKIES

It has been mentioned previously that coarse, clastic materials continued to accumulate in some parts of the area after the close of the Pennsylvanian period. An examination of the map showing the thickness of the Permian strata (Fig. 3) reveals the probability that only a small part of the Pennsylvanian land mass remained above water during

[1] Charles W. Tomlinson, *Oklahoma Geol. Survey Bull. 46* (1929); also *Bull. 40-Z* (1928).

[2] Robert H. Dott and Frank Gouin, *Oklahoma Geol. Survey Bull. 40 K* and *40 M*.

[3] *Ibid. 40 E, 40 M*, and *40 DD*.

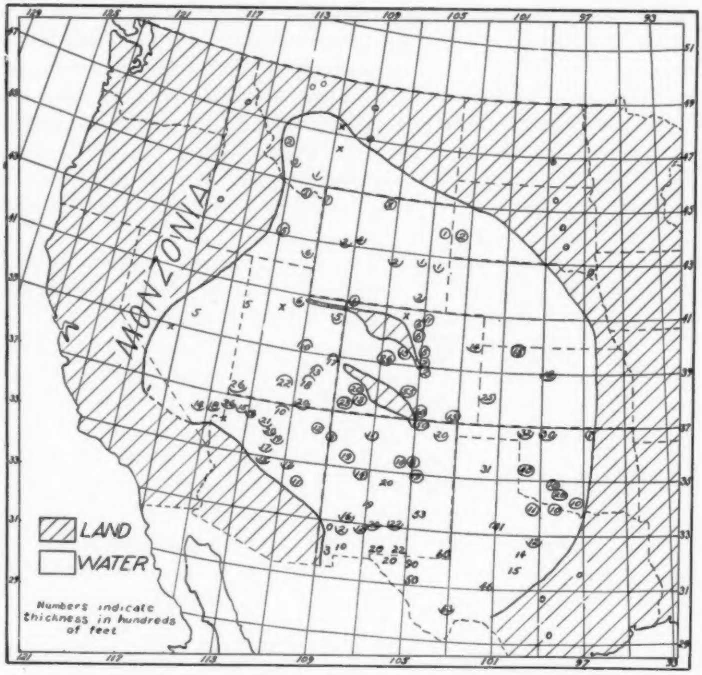


FIG. 3.—Map of the Cordilleran basin showing the Ancestral Rockies during Permian time and the thickness of the sediments of that system. Numerals denote thickness in hundreds of feet. Circles and parts of circles around the numerals indicate proportional amounts of clastic materials. Crosses indicate that Permian is present, but thickness not known.

Permian time. The Uinta-Front Range element seems, from the adjacent sedimentary record, to have been low-lying and capable of furnishing only a little sand. In Utah, for instance, the Park City formation contains much limestone, but also some shale, sandstone, and phosphate. In northwestern Colorado, the Park City formation is somewhat more clastic and contains only a small proportion of limestone. Along the east side of the Front Range element, red clays, silts, and sands accumulated to form the Lykins formation. This formation also contains much gypsum, indicating an absence of land-derived sediment. In southern Wyoming, the Forelle and Satanka formations occupy the basal part of the succession, but are succeeded by sediments similar to the Lykins (Chug-

water). Farther south, along the Front Range element, where the Forelle and Satanka are missing, the Lyons sandstone forms the base of the Permian. Parenthetically, it should be added that most of the original Lyons sandstone is regarded by Lee as of upper Pennsylvanian age.[1]

South of the Uinta-Front Range element, Permian rocks are reported from the Tenmile district and the Aspen district. In the Tenmile district the "Wyoming" red shale, sandstone, and conglomerate are 1,500 feet thick. At Aspen the "Triassic" red beds are probably of Lykins age and are 2,600 feet thick.

On the northeast side of the Uncompahgre-Sangre de Cristo element Melton reports 5,500 feet of Permian rocks at Crestone. This is the upper part of the Sangre de Cristo formation. Inasmuch as none of these rocks contains fossils, the reason for assigning them to the Permian may seem somewhat arbitrary. Plentiful confirmatory evidence, however, may be found on the southwest side of the same element. There, the Cutler formation in the Ouray quadrangle is 2,000 feet thick and consists of red sandstones which contain many conglomerates to the very top. These conglomerates contain boulders of pre-Cambrian granite, greenstone, schist, and quartzite. Similar conditions exist in the Silverton, Telluride, Needle Mountains, Engineer Mountain, and Rico quadrangles, except that the Rico formation comes in at the base of the Permian under the Cutler. The latter is unfossiliferous and the Rico contains a fauna with both Permian and Pennsylvanian aspects. We might, therefore, be led to wonder whether they are correctly placed in the Permian. If they are, however, the conclusion would not alter conditions; for the overlying Dolores formation, in which Triassic fossils have been found, also shows the presence of a high land mass near by. Incidentally, it seems reasonable to suppose that the Shinarump conglomerate, which separates the Triassic Chinle and Moenkopi formations, and occurs in a remarkably wide area in Utah and adjacent states, was derived from the same land mass.

The Permian rocks west and southwest of the Uncompahgre element have recently been described by Baker and Reeside.[2] Much of the confusion which prevailed in the nomenclature has been cleared up by their new correlations, new definitions, and, especially, by their elucidating cross sections. These show the gradual thinning of the Coconino sandstone toward the west and its gradual replacement by the Kaibab limestone.

[1] Willis T. Lee, *U. S. Geol. Survey Prof. Paper 149.*

[2] A. A. Baker and John B. Reeside, Jr., *Bull. Amer. Assoc. Petrol. Geol.,* Vol. 13, No. 11 (November, 1929), p. 1423 ff.

The fact that the Defiance-Zuñi element was completely submerged under these Permian sediments indicates that the main source of the sand and mud was the Uncompahgre element. It should be added, however, that the Defiance element was probably subject to erosion until nearly the end of Coconino time. In New Mexico the gradual change from clastics at the north to non-clastic deposits toward the south also indicates that the Uncompahgre-Sangre de Cristo element was supplying the materials.

SOURCE OF PERMIAN RED-BEDS

These considerations lead us to inquire where the Red-beds came from which now form so large a part of the stratigraphic section in the Mid-Continent area. Much has been written regarding this difficult subject and the suggested possibilities have been many. A study of the data shown on the Permian isopach map should help to solve this problem. It is noticeable that the greatest thickness is to be found in western Texas, but that nearly equal thicknesses are to be found around the Uncompahgre-Sangre de Cristo element. These two sets of figures are not at all comparable, however, because the first set applies almost entirely to chemical sediments and the latter mostly to mechanical sediments. In West Texas and southeastern New Mexico, the Permian consists of dolomite, limestone, gypsum, salt, and anhydrite, with only a very small amount of clastic material. Elsewhere in the Cordilleran basin the relations are reversed and chemical sediments form only a minor constituent of the section. On the basis of both thickness and lithologic character, it becomes evident that the Ancestral Rockies of Permian time were a very important source of sediment.

It also seems certain that the land mass which existed in the southern half of Arizona and southern California furnished much clastic material for Permian shore currents to distribute. The rocks exposed along the old shore line in that part of the basin consisted largely of pre-Cambrian granites and quartzites. Furthermore, southwestern Arizona seems to have been a land mass ever since pre-Cambrian time, and western Arizona was submerged only during the Mississippian and Pennsylvanian periods. Degradation of this large area must have supplied much sand and mud to the epi-continental sea for every system except the Mississippian and Pennsylvanian. The remarkably uniform distribution of the Abo sandstone (at the base of the Permian) implies a southern source as well as a northern source.

The part of the Cordilleran basin in which the petroleum geologist is most interested lies in western Oklahoma, the Panhandle of Texas,

and western Kansas. Thicknesses ranging from 2,000 to 4,000 feet seem to be the general rule, except near positive areas, and perhaps 3,000 will be found to be a common average thickness. If the drill records are studied, it will be found that the proportion of clastic material to non-clastic is largest in the eastern part of this area, and gradually decreases toward the west. This indicates clearly that most of the sand and mud which make up the Red-beds of northern Texas, western Oklahoma, and central Kansas were derived from the land mass lying on the east. The Permian shore line on the east side of the Cordilleran basin probably corresponded approximately with the present position of Missouri River as far south as Kansas City, and thence continued south toward Mc-Alester and Denison. East of this shore line lay a land mass on which much limestone was undergoing erosion and weathering. Those who have seen the red residual clay which is now forming in the Shenandoah Valley and in Kentucky as a result of weathering of similar limestones, will conclude that much of the red sediment had its source in Iowa and, especially, Missouri. The sands probably came largely from eastern and southeastern Oklahoma.

In this connection we must not overlook the fact that the Wichita Mountain core of granite and diorite was a small land mass, and that some of the materials from this source help to explain the greater thickness in the Anadarko basin and elsewhere. Finally, Llanoria must be considered, although our knowledge of its constitution and extent is mostly speculative. If we assume that the Stanley and Jackfork sandstones and shales extend under the Cretaceous cover of northeastern Texas, there would be a very prolific source of sand as a result of their degradation. The excellent maps and cross sections prepared by Cheney,[1] showing the thickness of the Pennsylvanian sediments (included in the Strawn by Cheney) in that region and farther south along the edge of Llanoria, give us a clue. But this area is south of the Muenster arch and may have had a slightly different history.

SOURCE OF DATA FOR MAPS

The data which were used in the preparation of the three maps included in this discussion were derived from many sources. The publications of the United States Geological Survey supplied by far the greatest number. Most of the data for New Mexico were found in Darton's excellent report on the geology of the Red-beds.[2] Similarly, most of the

[1]See especially *Univ. of Texas Bull. 2913*, Pls. III, IV, and VIII.

[2]N. H. Darton, *U. S. Geol. Survey Bull. 794*.

data for the state of Arizona were found in Darton's "Resumé of Arizona Geology."[1] In order to enumerate all the articles which furnished information on the remainder of the area, nearly as much space would be required as the discussion occupies. Therefore, it will not be attempted. Some data were used which have not yet appeared in print. These data were supplied by Roy Hall, Anthony Folger, L. C. Morgan, and R. L. Clifton, all of whom have done much research work on the stratigraphic and tectonic problems of the Mid-Continent region.

A word regarding the numbers on the map may not be out of place. These numbers show the actual thickness as reported by some good authority and have not been added to by the writer in order to bring them up to the total thickness before erosion. However, most of the numbers used probably represent the full thickness for the spot indicated. As a rule, only thicknesses were plotted which include the base and the top of the system. In other words those stratigraphic sections were used which showed both the underlying and the overlying systems at least in part. Similarly, where a zero is plotted on the map it means that the older system and the younger system are present, but that the system in question is entirely missing.

It is believed that this method of plotting the distribution of the systems of rock produces a fairly accurate land and water map; for small and local spots of no thickness may be due to erosion, but large and consistent areas of no thickness mean no deposition. If the sediments of a certain system were laid down throughout a fairly large area and this area is assumed to be warped into relief of a low order, erosion would not be very effective and remnants would be left which probably would be found. If, however, the uplift of the sediments is pronounced so that erosion is great and rapid, the areas which are involved are probably small. Furthermore, structurally low areas near by may escape erosion and the sediments will probably be found in the section. Therefore, the three maps included in this article probably show the distribution of land and water more faithfully than have previous maps.

The quality of the data and the accuracy of the thicknesses plotted are not the same throughout. Some sections have been measured and described recently, others years ago. Some of the figures represent sections carefully measured with precise instruments, others mere guesses made in connection with reconnaissance work. The writer has tried to eliminate those data which were obviously out of harmony with adjacent figures. A few such data remain on the maps because the

[1] *Univ of Arizona Bull. 119* (Tucson, Arizona, October, 1925)

authority seemed to be very good. An example is the thickness of 9,000 feet for the Permian on the south end of the Guadalupe Mountains, which seems exceptional when compared with surrounding figures. Similarly, the thickness of 15,000 feet for the Pennsylvanian strata in the Oquirrh Mountains of Utah does not agree well with the other figures in that part of the basin.

It was not considered advisable to draw isopach lines for thicknesses because of the danger of obscuring other more important features. A study of the maps shows that the thickness of each system is remarkably uniform away from the land areas which formed the temporary boundaries at the time. The location of these border lands and the location and outlines of the islands show a very close correspondence. This, of course, is to be expected and tends to confirm the reliability of the data used. Thus, the shore lines of Laurentia, Ozarkia, Llanoria, Monzonia, and the land mass in southern Arizona and California remain in approximately the same or closely similar positions. More striking changes are shown in the outlines of the nucleus for the Ancestral Rockies. This was rather large in Mississippian time, became smaller and dissected during Pennsylvanian time, and much smaller in Permian time. During the ensuing Mesozoic era, it became completely submerged and lost its identity until the violent diastrophic movements of early Tertiary time restored its ancient outlines.

GEOLOGICAL NOTES

UNCONFORMITY IN COLORADO GROUP IN EASTERN COLORADO[1]

Several years ago, while making a study of the stratigraphy of a part of the Pueblo Quadrangle in connection with field work for the Colorado School of Mines, the writer formed the opinion that an unconformity, or at least a diastem, exists between the Benton group and the Niobrara formation. During the last year he has been making a study of the Benton formations in eastern Colorado and has found considerable evidence favoring this idea.

L. W. Stephenson,[2] in his recent paper, summarizes the criteria that may be useful in the recognition of sedimentary breaks within a series of fine marine sediments as follows.

1. A thin conglomerate composed of pebbles, bones, teeth, and other hard objects, mechanically re-worked in the base of an overlying formation.
2. A thin layer of phosphatic nodules and phosphatic fossil casts of organisms. This layer generally means a stratigraphic break, but it may be difficult to determine whether it marks a diastem, a minor unconformity, or a major unconformity.
3. A phosphatic layer which includes water-worn materials obviously derived from older formations, such as fossil shells, phosphatic fossil casts, bones, shark teeth, pebbles, and rock fragments. This generally marks an unconformity caused by emergence and erosion.
4. Sharp differences in the lithology of the materials below and above the contact between two beds. This alone is not sufficient to prove an unconformity, as such differences may have been caused by an abrupt change in the character of the sedimentation.
5. An uneven or undulating contact which cuts across the bedding planes of the underlying formation. This marks an unconformity caused by emergence and erosion.
6. The presence of distinctive faunal zones immediately below and above a contact, which zones are known to be separated elsewhere by sedimentary beds of greater or less thickness.
7. Discordance in the dip of the beds below and above a contact.....

[1]Read before the Association at the New Orleans meeting, March 22, 1930. Manuscript received by the editor, March 4, 1930.

[2]L. W. Stephenson, "Unconformities in Upper Cretaceous Series of Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 10 (October, 1929), p. 1325.

8. Borings made by marine organisms of the littoral zone, which extend from the contact downward into the underlying beds to depths of 18 inches or more, filled with material like that composing the bed above the contact.

All of these can be found variously developed in connection with the Benton-Niobrara contact.

For the convenience of those not acquainted with the stratigraphy of southeastern Colorado, a summarized table of formations is here given, the exposure in Wild Horse Park serving as an example of the common sequence.

GENERALIZED TABLE OF FORMATIONS FOUND IN WILD HORSE PARK

Age		*Name*	*Thickness (Feet)*	*Character*
		Pierre		
CRETACEOUS		Niobrara	600	Light gray calcareous shales above, weather yellow to tan Light gray limestone at base, weathers white
CRETACEOUS	BENTON GROUP	Carlile	180-200	Yellow to tan sandstone at top, with small scattered concretions near its base Gray to black shales form lower part of the formation and comprise at least 2/3 of its thickness A zone of large concretions occurs about the middle of the shale
CRETACEOUS	BENTON GROUP	Greenhorn	40-45	Alternating limestone and shales. Limestones dark gray to black when fresh—weather light gray. Shales dark gray to black—some very calcareous. Bentonite streaks present in the shales
CRETACEOUS	BENTON GROUP	Graneros	200	Shale—dark gray to black. Some slightly sandy layers in upper part. A few thin limy beds present in lower parts
		Dakota		

Considering the various criteria mentioned,[1] we find that a thin conglomerate containing plentiful fish teeth, well rounded pebbles, and phosphate nodules occurs at the base of the Niobrara in all the areas studied. This conglomerate ranges in thickness from a fraction of an inch to a foot. In many places, the teeth are present in surprisingly large numbers. In a few places, samples were taken of which teeth made up more than 40 per cent of the volume of the rock. The pebbles of the

[1] *Op. cit.*

conglomerate are ordinarily rather small, but some are 2 or 3 inches in diameter. They are all very smooth and well rounded; generally they are somewhat flattened. Most of these pebbles consist of a black chert, but quartzite, white quartz, and a few other minerals have been noticed. In some localities many phosphate nodules and fragments were found. A sample of the phosphate was analyzed at the experimental plant at the Colorado School of Mines by F. G. Hills. The following composition was obtained.

K_2O	1.11	Fe_2O_3	3.43	CO_2	7.10
Na_2O	0.93	CaO	43.30	MnO	0.02
SiO_2	10.20	MgO	2.10	SO_2	1.03
FeO	1.55	P_2O_5	27.24	Al_2O_3	1.84

The cementing material is calcareous, and where the constituent particles are small the rock in general appears as a gray to brown crystalline sandy limestone.

It might be noted also that this conglomerate, or at least its upper part, ordinarily has an appearance of considerable oxidation. It is commonly a rich limonite, brown in the region around Pueblo.

The writer has studied this conglomerate carefully in the vicinity of Wild Horse Park in the north-central part of Pueblo Quadrangle and has found it present in all the outcrops which he examined in El Paso, Fremont, Pueblo, and Huerfano counties. It was observed in Las Animas County. A similar conglomerate is present in the vicinity of Golden and in the general area east of Denver. According to John G. Bartram, of the Midwest Refining Company, it is widespread throughout southeastern Colorado and counties southward and extends into the adjoining parts of New Mexico. C. S. Lavington, of the Continental Oil Company, reports having found it in the areas he studied in southeastern Colorado. W. Z. Miller mentions having observed it in western Kansas, where it is on the Codell sandstone.

According to Stephenson, such a conglomerate layer, containing shark teeth, phosphate nodules, and hard rock fragments, generally marks an unconformity caused by emergence and erosion.

There is a decided lithologic change at this contact. The material below is a sandstone of fine to medium texture (except the thin, irregular top part), and the overlying material is pure and massively bedded limestone. Such a change in lithology does not in itself necessarily imply an unconformity, but is very suggestive when considered with other evidence. The contact surface at places is slightly uneven or undulating. At no point, however, was a perceptible discordance in

dip observed. A study of many measured sections and well logs shows a marked difference in the thickness of the Carlile sandstone. The thickness ranges from a few inches to about 50 feet. In a few places in eastern and northeastern Colorado, a series of sediments occurs between what appears to be the Carlile sandstone and the typical Niobrara limestone. This is particularly well developed in northeastern Colorado (Yuma County). Similarly in the lower Huerfano Basin, near Badito post office, some shales and a thin limestone occur above the Carlile, but are separated by an erosion surface from the overlying Niobrara.[1] Also, there is a variation in the thickness of the lower limestone part of the Niobrara at several localities, and according to Professor Keyte,[2] the faunal evidence strongly suggests that the lower limestones are not everywhere of the same age, but that locally some of the beds were not deposited.

In some places these variations may represent lateral variations of sediment such as are normal when deposition takes place along and close to an irregular coast. But they can not be completely explained on that assumption. At the Bedito locality, the Carlile sandstone is exceptionally thick and is overlain by post-sandstone beds. The same thing is suggested by the Yuma County well logs, that is, the post-sandstone beds are best developed where the Carlile is exceptionally thick.

The great differences in thickness of the Carlile sandstone seem, to the writer, very suggestive of an interval of erosion. This sandstone changes in thickness within very short distances in eastern Colorado, and, according to Miller, the same is true for the corresponding Codell sandstone of western Kansas. Cross, in his description in the Pike's Peak folio, mentions a decided thinning of the entire Benton formation, which suggests an overlapping of the Niobrara in the area south of Pike's Peak.[3]

Where the upper Carlile sandstone has been carefully studied (in the northwestern part of the Pueblo Quadrangle), it was repeatedly noticed that the upper sandstone layers are literally filled with casts of borings made by marine organisms. Ordinarily these had been filled with sand, much of which had a somewhat different appearance from the bulk of the rock. In a few places, calcareous material occupied low places at the top of these.

[1]H. W. C. Prommel, consulting geologist, Denver, Colorado. Personal communication.

[2]I. A. Keyte, professor of geology, Colorado College, Colorado Springs. Oral communication referring particularly to the section near Owl Creek, Larimer County, as compared with sections on Arkansas River near Florence and Concrete.

[3]C. W. Cross, *U. S. Geol. Survey Geologic Folio* 7 (1894), pp. 2 and 4.

Faunal evidence.—Fossils are fairly plentiful in the Carlile in many localities, especially in the Huerfano Basin and in the Arkansas River valley. In general, they become progressively scarcer northward and are rare north of the latitude of Denver. In the Niobrara, with the exception of *Inoceramus deformis*, which is common in a certain zone, and small oysters commonly referred to *Ostrea congesta*, fossils are rare.

A study of published faunal data and of fossils in the several collections in Colorado shows that less than half of the forms known from the Carlile have ever been found in the Niobrara, and a still smaller proportion of the Niobrara fossils have ever been obtained in the Benton formations below.

J. B. Reeside, Jr.,[1] has prepared the following lists which show the distinct faunal differences between the Niobrara and upper Carlile faunas if viewed over a large area. Not all of these species have been found in the region discussed.

Niobrara, but not Benton
- *Marsupites* sp.
- *Uintacrinus socialis* Grinnell*
- *Inoceramus deformis* Meek*
- *Inoceramus stantoni* Sokelow*
- *Inoceramus undulatoplicatus* Roemer
- *Inoceramus subquadratus* Schluter
- *Inoceramus umbonatus* Meek and Hayden
- *Inoceramus exogyroides* Meek and Hayden
- *Inoceramus erectus* Meek
- *Inoceramus* (*Haploscapha*) *grandis* Conrad*
- *Sauvagesia* aff. *S. austinensis* (Roemer)*
- *Phylcticrioceras oregonense* Reeside
- *Baculites codyensis* Reeside
- *B. asper Morton* (ranges above Niobrara but not below)
- *Scaphites vermiformis* Meek and Hayden and varieties
- *S. ventricosus* Meek and Hayden and varieties
- *S.* sp., several unnamed forms
- *Binneyites parkensis* Reeside
- *Barroisiceras* sp., several unnamed species*
- *Mortoniceras shoshonense* Meek
- Various vertebrates*

Carlile, upper, not known from Niobrara
- *Inoceramus dimidius* White
- *Inoceramus fragilis* Hall and Meek
- *Exogyra suborbiculata* Lamarck
- *Ostrea lugubris* Conrad
- *Pugnellus fusiformis* Meek
- *Scaphites warreni* Meek and Hayden
- *Prionocyclus wyomingensis* Meek
- *Prionotrophis hyatti* Stanton
- *Coelopoceras* sp., several species

*Occur particularly in limestone or chalk facies; others in shaly or sandy facies only.
Notice also: *Inoceramus deformis* is consistently lower Niobrara. All *Barroisiceras* are lower Niobrara.

[1] J. B. Reeside, Jr., personal communication dated January 25, 1930.

In considering these faunal differences, one must, of course, allow something for the difference in lithologic character of the formations, but it does not seem at all reasonable to explain all the differences on this basis, particularly where the decided lithologic change has to be accounted for also.

The facts which have been presented seem to the writer to indicate the undoubted existence of an unconformity between the Benton and Niobrara in eastern Colorado and adjoining areas. How great a time interval is represented by this unconformity he is not at present prepared to state. Evidently the amount of time represented is not the same in all places. In general, however, it seems to have been of considerable duration, sufficient time, at least, having elapsed to account for a complete cessation of deposition of one type, its alteration, and, in places, partial erosion and the development of conditions under which sediment of a completely new type was deposited. During this time life made considerable development so that new elements appear in the Niobrara fauna.

J. Harlan Johnson
Associate professor of geology

Colorado School of Mines
Golden, Colorado
March, 1930

PUBLICATION OF ORIGINAL RECOMMENDATIONS

Rarely are we informed of the precise reasoning on which the discovery well of a modern oil field was located.

The average paper published after discovery deals chiefly with features found by the drill, with perhaps the mention that "the discovery well was located as a result of geologic investigations which revealed a favorable condition." Such papers carefully tell me all except the one thing I most want to know—what was the original reasoning of the geologist who found some weathered outcrops in a field and recommended that some company spend a hundred thousand dollars there? One page of a meager report written prior to discovery will teach me more than many pages written afterward. The following is submitted in explanation of my viewpoint.

Discoveries fall into two general classes: (1) fields recommended because local structure, stratigraphy, or seepage is clearly analogous to that in localities known to be productive; (2) fields recommended although the local features are not clearly analogous to those in productive localities. Discoveries of the first class support and continue general

belief. Discoveries of the second class attack and modify general belief. Both classes add to our knowledge, but the second class is the more valuable because each discovery may be the type of a new series.[1]

There are two kinds of reasoning, inductive and deductive. Induction is reasoning from particulars to the general, deduction is reasoning from the general to particulars. Induction gives us principles and general rules, deduction applies these. In general, we create by induction, we copy by deduction. A few inductive thinkers create patterns, and the masses then trace these mechanically until another inductive thinker modifies them. The patterns furnished by Galileo, Columbus, Darwin, Pasteur, Marconi, and others, have been followed by millions. A few thousand have contributed modifications.

Petroleum geology is in the main deductive, because we study, believe, and apply general rules furnished by others. We deduce most local relations from controls given us. Thus, most oil fields have been discovered because it was recognized that the local conditions closely resembled those in productive fields.

Petroleum geology is in part inductive, because we sometimes stray from the narrow path, think for ourselves, and doubt the infallibility of general beliefs.[2] Such straying is dangerous, but it occasionally reveals new truths. Oil fields discovered with the aid of induction (without clear analogy) teach us something new, and are by all odds the most valuable fields for study.

In geology, as in all human vocations, we are inclined to emphasize deduction at the expense of induction. Primary instruction in petroleum geology stresses deduction, the student being taught general beliefs, and being encouraged to deduce local relations from these. Although necessary, this is dangerous, for youth thinks in absolute terms. The substance of our knowledge of petroleum geology on graduation is likely to be a remembrance of generalities, such as that oil is most commonly found in anticlines, in some places collects against a fault, and has been known to occur in porous lenses.

We mold such impressions together to make a kind of bushel basket, and this we clamp mechanically over different structures. If a structure

[1]The geologist on whose recommendation Huntington Beach, California, was discovered is basically responsible for the subsequent rapid discovery of six additional fields along the Newport-Beverly shear zone. He who recommended Elwood is basically responsible for at least two subsequent fields in the local Miocene. He who recommended the first Seminole pool, Oklahoma, is responsible for certain adjacent pools, and so on.

[2]Phrases implying infallibility, such as *everyone agrees*, *it is generally accepted*, *authorities consider*, and *it is contrary to European views*, are meaningless in argument, and merely delay the progress of science.

does not exactly fit our measure, we discard it. If it fits our measure, we drill it, and ordinarily draw a blank. In California, our most successful geologic departments average only about one field out of twenty wildcats. Something must inevitably be wrong with our bushel baskets. How can we improve them? The most logical method seems to involve a study of the new inductive (creative) reasonings which prove successful.

Here is the point. A geologist recommends nineteen wildcats, and is wrong each time. He recommends a twentieth, and is right. As perhaps many geologists previously fitted their bushel baskets over that structure, shook their heads, and passed on, the successful man must have used a different measure. He must have diverged at least slightly from general belief, and therefore must have reasoned creatively. *His pre-discovery reasonings immediately become some of the most vital data of the science of petroleum geology.*

The successful geologist publishes a paper on his field, but, as a rule, he does not give what would really help me. He discusses almost entirely features uncovered by the drill. He presents a beautiful contour map based on wells, states that these wells passed through so much sand, shale, and limestone, and that they prove that closure exists. He evidently thinks that his pre-discovery reasoning based on meager surface data (and now shown to be erroneous in some particulars) should be thrown out, and the more accurate post-discovery data substituted. Therefore, he discards his pre-discovery reasoning—the pure gold—and gives us a mechanical list of well findings. He has discovered an oil field, but he has contributed little to the science of petroleum geology.

It is my contention that the most valuable data which this successful geologist can contribute to our science, are the *pre-discovery* reasonings on which he recommended the area.

In connection with California, I should like to read the pre-discovery reasoning on which Frank A. Morgan recommended the Elwood field after it had been condemned by nearly every prominent geologist in the state; also the pre-discovery reasoning of Hoyt S. Gale on the Fruitvale field, which we passed over, unseeing, for 20 years.

When an oil field is discovered by creative geology, I want to read the report in which the geologist staked his reputation. I want to read the recommendation at which we laughed. Views held subsequent to discovery are interesting, but those held prior to discovery are vital. Unfortunately, few geologists separate pre-discovery views from those resulting from subsequent drilling, partly because the former contain some mistakes.

Since petroleum geology can have no more important data than the reasonings on which new oil fields are discovered, I suggest the following method of preserving and disseminating such data.

1. If a paper is written by the geologist responsible for development, let him include his pre-discovery reasoning by quoting his original recommendation if such disclosure does not violate confidences or directly give competitive information.

2. Let quotations be verbatim, with no corrections except those of spelling, punctuation, and grammar; for original errors of judgment furnish valuable negative data.

3. In quotations from a long recommendation, it is preferable merely to give vital extracts, but such extracts should not be so selected as to suppress valuable errors of judgment.

4. It seems advisable that the geologist correct and amplify his original reasoning in prior or subsequent parts of the paper, or in insertions bracketed within the quotations, but it should be clear that all such correction or amplification was not a part of the original reasoning.

In time, the American Association of Petroleum Geologists may be able to publish a thin volume entitled "Original Reports Recommending Certain American Oil Fields." The contents will teem with errors, and the styles may be mixed and poor; but I will accord such a volume first place in my library on petroleum geology.

J. E. Eaton

Los Angeles, California
April 9, 1930

TYPE LOCALITY OF A FAULT

The evolution of mapping from reconnaissance to detailed work may cause difficulties in connection with early-named faults. An illustration is taken from the San Gabriel Mountains of southern California. The Sierra Madre fault[1] recently has been found to be discontinuous and has been resolved into two arcuate faults separated by folded structure.[2] Which fault, if either, should be called the Sierra Madre? After due consideration, Sierra Madre was retained as a zone term, and both faults were given new names.[3] If a type locality had been described

[1] W. S. W. Kew, "Geology and Oil Resources of a Part of Los Angeles and Ventura Counties, California," *U. S. Geol. Survey Bull. 753* (1924), pp. 100-01.

[2] H. J. Buddenhagen and Mason L. Hill, manuscript map of part of the San Fernando Quadrangle, California.

[3] Mason L. Hill, "Structure of the San Gabriel Mountains, North of Los Angeles, California," *Univ. California Pub., Bull. Dept. Geol. Sci.*, Vol. 19 (1930), No. 6, pp. 137-70.

originally, that fault which included the type locality might have kept the name Sierra Madre.

It has long been customary to indicate definitely the type localities of geologic formations. We suggest that a similar practice would be desirable for named faults.

H. J. Buddenhagen
Mason L. Hill
Frank S. Hudson
A. O. Woodford

Los Angeles and Claremont, California
April, 1930

PRE-PENNSYLVANIAN STRATIGRAPHY OF BIG LAKE OIL FIELD, REAGAN COUNTY, TEXAS

INTRODUCTION

Since the completion of the deep discovery well at Big Lake, the age of the producing horizon has been in question. It has been variously reported from Permian to lower Pennsylvanian. Ray V. Hennen,[1] as early as November, 1928, while the well was still being drilled, stated, "The bottom of the hole is believed to be in pre-Pennsylvanian rocks," and shortly afterward,[2] when the production had been found, he said, "It is believed that this deep oil zone (Fourth) occurs in the pre-Pennsylvanian, a conclusion seemingly corroborated by the analysis of the oil herein." No other supporting evidence for this conclusion was given.

In the early part of February, 1930, John E. Millar, of the Prairie Oil and Gas Company, obtained cuttings from the discovery well and after an examination reported to the operators and other interested parties that the oil was coming from the Ordovician. At the February 26th meeting of the Stratigraphic Society of Tulsa, he made an informal announcement that he had recognized Ordovician strata at Big Lake.

It has subsequently been announced[3] that Bruce H. Harlton and Frederick A. Bush had seen cuttings from the discovery well prior to Millar's announcement and had recognized the presence of Ordovician strata.

[1]Ray V. Hennen, "Big Lake Oil Pool, Reagan County, Texas," *Structure of Typical American Oil Fields*, Vol. II (Amer. Assoc. Petrol. Geol., 1929), p. 512.

[2]*Op. cit.* Appendix, p. 533.

[3]Bruce H. Harlton, "Ordovician Age of the Producing Horizon, Big Lake Oil Field, Reagan County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 5 (May, 1930), pp. 616-18.

Other wells have now been drilled into the pre-Pennsylvanian strata. The cuttings from these have been available and the results of the studies on the Silurian have been summarized in a previous issue of the *Bulletin*.[1]

The writer wishes to express his appreciation to the geological department of the Prairie Oil and Gas Company for permission to examine the samples and to publish the information derived from them. Thanks are due to Mr. Millar for having called this interesting information to the writer's attention and for his many helpful suggestions during the preparation of this paper. The writer also wishes to thank the Mid-Continent Petroleum Corporation for permission to publish the following results of his work on this problem.

STRATIGRAPHY

The pre-Pennsylvanian strata that have been recognized at Big Lake are closely similar to parts of the Arbuckle Mountain section of central Oklahoma. They include parts of the Hunton limestone, Sylvan shale, and Simpson group. Figure 1 is a columnar section of the strata that already have been recognized at Big Lake. Other members of the pre-Pennsylvanian section may be found in wells drilled farther down the dip.

One important angular unconformity is found at Big Lake that has not been noticed in Oklahoma. This occurs between the Sylvan shale (Richmond) and subjacent Ordovician strata of Chazy age. It is suggested that the disturbance which caused the aforementioned unconformity at Big Lake may be Trenton or lower Cincinnatian, or both.

ORDOVICIAN

Unfortunately the lowest 11 feet penetrated in the discovery well (8,514 - 8,525 feet) was not represented in the cuttings available and it seems that there is no record of its having been saved. The cuttings from 8,510 to 8,514 feet showed limestone that is strikingly different from limestone in the cuttings above,—sufficiently different to indicate the presence of a formational boundary at 8,510 feet. Since Millar announced that the oil is being produced from the Ordovician, it has been rumored that it is "Wilcox." This can not be correct, for whereas the "Wilcox" is upper Simpson (Black River) in age, the deep discovery producing horizon at Big Lake is overlain by Simpson (Chazy) and is probably pre-Simpson in age. It is suggested that the Ordovician producing horizons at Big Lake be called Marathon, for the Marathon series which crops out in Brewster County, West

[1]S. W. Lowman, "Silurian at Big Lake," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 5 (May, 1930), pp. 618-19.

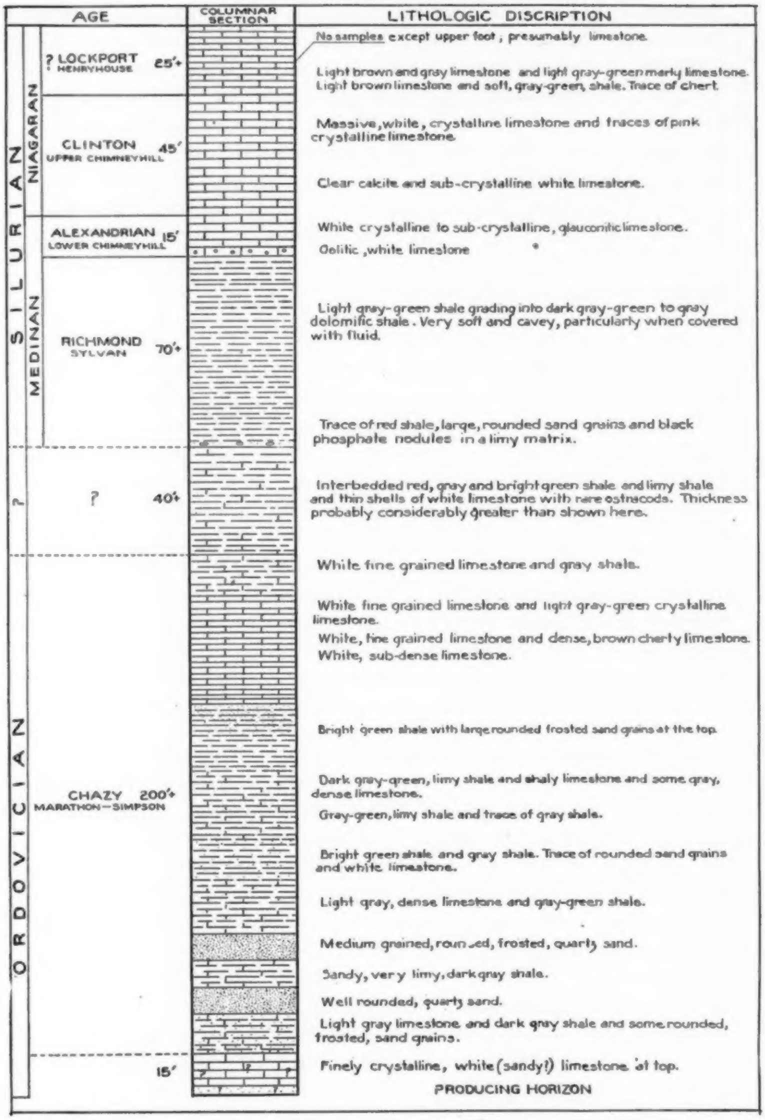


FIG. 1.—Columnar section of strata at Big Lake. Thickness shown in feet.

Texas, includes strata of both Simpson and pre-Simpson age and is the only Texas representative of the Simpson group.

The cuttings from the discovery well, from 8,335 to 8,510 feet, showed a series of Ordovician fossiliferous gray-green shales, light gray limestones, and a few thin beds of sand. The lithology of the shales, the limestones, and the sands is strikingly like that of the Simpson group of Oklahoma. E. H. Sellards, in his *News Letter* for April, 1930, says,

> ....cores from depth 8,431 to 8,488 feet obtained early in April by Dr. H. B. Bybee, contain macro-fossils which have been identified by Dr. E. O. Ulrich as representing Chazy, equivalent to a horizon well down in the Simpson.

Sellards does not state from which well these were obtained, but the date indicates the Big Lake Oil Company's University No. 1-C.

The Sylvan shale unconformably overlies the Chazy in the discovery well, but in the west offset (the Big Lake Oil Company's University No. 1-C) 40 feet of strata of undetermined age wedge in between. These strata are composed of soft shales and thin limestones. The shales are gray, gray-green, bright green, reddish gray, and reddish brown. Some layers are non-calcareous, some are very calcareous, and some are so crowded with crystals of calcite or dolomite that one is tempted to call them crystalline shales. The limestones are gray to white in color, crystalline to dense in texture, and are sparingly fossiliferous. As this group seems to lie below the unconformity, it is thought to be of Ordovician age. Whether it is Chazy or younger is not known.

The Black River stage of the Ordovician is very well represented in both the Simpson group and the Marathon series. It is the most widespread stage of the Ordovician and it would be well to look for it between the Sylvan shale and the Chazyan in wells drilled farther down the dip. The Black River part of the Simpson carries the most productive sands in Oklahoma. Remembering the experience of flank production at Oklahoma City, the writer suggests that wells as far from the top of the Ordovician "high" as the Big Lake Oil Company's University No. 4-C seems to be may still be regarded as extremely interesting tests. No. 3-C is producing from a horizon that is below the Sylvan and seemingly above the strata that Ulrich identified as Chazy.

SILURIAN

E. O. Ulrich has maintained that the Richmond stage, which is commonly placed at the top of the Cincinnatian division of the Ordovician, is more properly considered the lower stage of the Medina division of the Silurian. Though this classification is contrary to that of most other

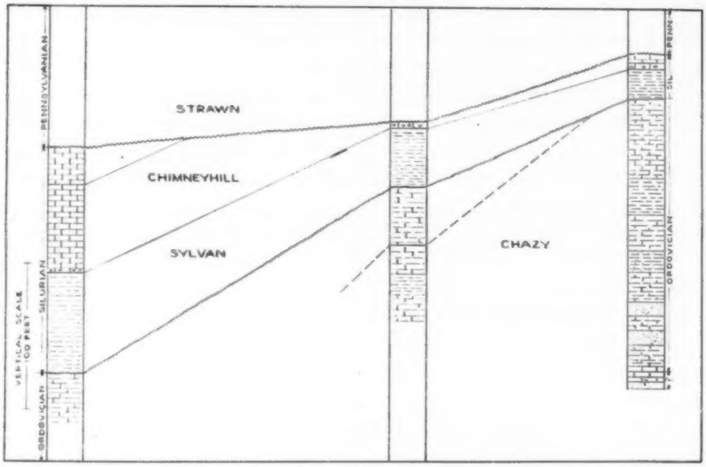


FIG. 2.—Sections showing unconformity between Pennsylvanian and Silurian and between Silurian and Ordovician.

stratigraphers, it is used here because at Big Lake a series of Niagaran-Alexandrian-Richmond strata is separated by marked angular unconformities from the Pennsylvanian above and the Ordovician below, as shown in Figure 2.

Sylvan.—The Richmond is represented in Oklahoma by the upper member of the Viola that is correlated with the Fernvale limestone of Tennessee, and the overlying Sylvan shale that is correlated with the Maquoketa shale of Iowa. The lowest Richmond horizon that has been recognized at Big Lake is the upper part of the Sylvan, which is similar to the Sylvan of Kansas and Oklahoma. It overlaps the Ordovician "high" and rests on the Ordovician with marked angular unconformity. In the discovery well there are only 20 feet of the highest part of the formation present, whereas in wells farther down the dip, successively lower parts of the formation are found. In the Big Lake Oil Company's University No. 3-C, the Sylvan shale is 70 feet thick. At the point that seems to be the bottom of the Sylvan in the three wells that have been drilled through it, there is a little limy, rounded sand containing some phosphate nodules. This is thought not to occur in the same bed, but in progressively overlapping beds and is considered to be additional evidence of unconformity. There are Fernvale faunas in the upper

Maravillas chert of the Marathon uplift and in the Montoya limestone of the El Paso district, and the Fernvale is thought to have been recognized at the depth of about 4,400 feet in the South Bend pool, southern Young County. Therefore, it seems reasonable to suggest that the Fernvale may be found under the Sylvan in wells drilled farther down the dip at Big Lake.

Hunton.—The Hunton limestone is one of the major oil-producing horizons in central Oklahoma. It is excellently exposed at many localities in the Arbuckle Mountains, where Chester A. Reeds[1] made it the subject of a special study and divided it into five formations. He assigned the upper three formations (Frisco, Bois d'Arc and Haragan) to the lower Devonian and the lower two (Henryhouse and Chimneyhill) to the lower Silurian.

TABLE I

LOG OF SILURIAN STRATA IN BIG LAKE OIL COMPANY'S UNIVERSITY NO. 3-C*

Formation	*Feet*
Base of PENNSYLVANIAN, re-worked, residual limestone conglomerate	8,579-8,585
SILURIAN	
Henryhouse? porous dolomite or limestone and gray-green marl	8,585-8,410
Chimneyhill; white, crystalline to subcrystalline limestone with	
3a. Traces of pink limestone	8,410-8,440
3. Plentiful clear calcite	8,440-8,460
2. Traces of glauconite	8,460-8,473
1. Rare oölites	8,473-8,477
Sylvan shale	8,477-8,535
Top ORDOVICIAN	8,535

*Missing or cavy cuttings obscure many of the contacts.

The lithology of the Henryhouse(?) division in 3-C from 8,385 to 8,410 feet could be matched quite as easily in the Haragan formation of the Hunton as in the Henryhouse. However, beds of Haragan (lower Devonian) age are not known on the outcrop or underground in Texas, whereas the Fusselman limestone of the El Paso district is known to be of approximately the same age as the Henryhouse (middle Silurian).

The upper Chimneyhill (bed 3a), from 8,410 to 8,440 feet, has much less pink crystalline limestone than is ordinarily found at this horizon in Oklahoma. The lower Chimneyhill (beds 2 and 1), from 8,460 to 8,477, has very little glauconite and very rare oölites compared with the lower Chimneyhill glauconitic limestone and oölite of Oklahoma.

The lithology of bed 3 (clear calcite and subcrystalline limestone), from 8,440 to 8,460 feet, is not normal to either the upper or the lower

[1]Chester A. Reeds, "The Arbuckle Mountains, Oklahoma," *Natural History*, Vol. 26, No. 5 (September-October, 1926), reprinted as *Oklahoma Geol. Survey Circular 14* (1927).

division of the Chimneyhill limestone as the writer has commonly found them in Oklahoma, but the St. Clair limestone of Arkansas, which is correlated with the upper (Clinton) member of the Chimneyhill limestone, is found to be largely composed of clear calcite in many places.

The Big Lake Oil Company's University No. 2-C is producing 650 barrels a day from the basal oölitic member of the Chimneyhill, the total depth being 8,231 feet. The Texon Oil and Land Company's University No. 2-B blew in from approximately the same horizon at 8,131 feet, making 15,000,000 cubic feet of gas and spraying oil. This was considered insufficient production and an attempt is being made to mud it off and drill deeper. In No. 2-C there is 40 feet of Chimneyhill above the oölitic member, whereas in 2-B there is 10-20 feet. In the Big Lake Oil Company's University No. 1-C and in the Texon Oil and Land Company's University No. 1-B, the oölitic member of the Chimneyhill is overlain by the Pennsylvanian, with possibly a little non-oölitic Chimneyhill intervening in No. 1-B. In the three wells (1-B, 1-C, and 3-C) that have been drilled into the Sylvan shale, it seems to be the upper part of the Sylvan that underlies the Chimneyhill. This contact therefore represents a true datum, and is a better datum to use for structural contouring than the top of the Hunton, which is an eroded surface overlapped by Pennsylvanian.[1]

The only correlative of the Hunton limestone known to crop out in Texas is the Fusselman limestone of the El Paso district. The Fusselman is a thick limestone that is of nearly the same age as the Henryhouse formation of the Hunton, but the exact relationship of the Fusselman fauna to the Niagaran fauna of the Mississippi Valley area has not been determined.

DEVONIAN

The Caballos novaculite of Texas, though unfossiliferous, is correlated on the basis of its lithology with the Arkansas novaculite, which is earliest middle Devonian in age, therefore younger than the Hunton. Neither it nor the Devonian Hunton is thought to be represented at Big Lake. The Percha shale, which is highest Devonian in age, has been recognized in West Texas. In some states the Chattanooga is classed as highest Devonian, in others as lowest Mississippian, and in still others as both Devonian and Mississippian. The Chattanooga in Oklahoma and Kansas is characterized by plentiful microscopic plant spores. A

[1]Robert Roth, of the Indian Territory Illuminating Oil Company, has recently studied the fusilines from the basal Pennsylvanian at Big Lake, which he regards as indicating basal Cisco. Other faunal studies have been regarded as indicating Strawn, for which see Bruce H. Harlton *op. cit.*

few spores that are exactly like those of the Chattanooga were found in the basal Pennsylvanian of the discovery well by Millar. Whether these are indigenous to the Pennsylvanian or derived from some near-by Chattanooga (Percha?) is not known.

MISSISSIPPIAN

The middle and upper Mississippian are represented in central Texas by the Boone limestone and the Barnett shale, and in the El Paso district by the Helms formation. No Mississippian has been recognized at Big Lake.

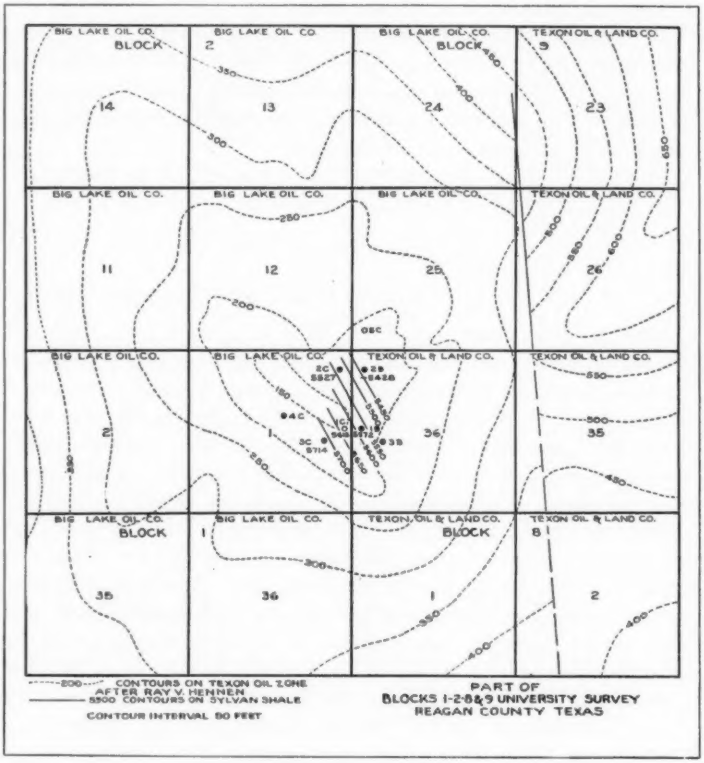


FIG. 3

STRUCTURE

There are so few data on the pre-Pennsylvanian horizons at Big Lake that they give little more than a suggestion of the structural relations of these beds. Only a part of the southwest flank of the structure on the Sylvan shale is shown, but it is enough to indicate that the rate of dip on the top of the Sylvan is nearly twice that on the top of the Texon zone, and that the crest of the structure on the top of the Sylvan may be as much as ½ mile east of the crest on the Texon zone. There are only two wells that have penetrated the lower Ordovician and these are not positively correlated. However, they indicate that the rate of dip on the Ordovician is nearly double that on the Sylvan.

Mr. Hennen's[1] interpretation of the structure on the top of the Texon zone places a fault on the east side of the field. Other interpretations close the field on the east side without faulting. The interpretation involving the fault suggests interesting speculation relative to the east closure of the pre-Pennsylvanian structure.

S. W. LOWMAN

TULSA, OKLAHOMA
May 13, 1930

QUARTER-CENTENNIAL, ILLINOIS STATE GEOLOGICAL SURVEY

Approximately one hundred geologists attended the Quarter-Centennial celebration of the present Illinois State Geological Survey at Urbana, April 30-May 1. The program, dedicated to the memory of T. C. Chamberlin and R. D. Salisbury, included four principal speakers on the "Historical Retrospect of Geological Investigations in Illinois and Their Relations to the State;" seven papers on "Research Needs of Illinois Coal Industry;" and nine papers and many discussions on "Studies Relating to the Order and Conditions of Accumulation of the Coal Measures." The Illinois Survey plans to publish these contributions.

Petroleum geologists engaged in work on the Carboniferous sediments will no doubt find much of interest in this third group of papers presented by J. Marvin Weller, H. R. Wanless, Wilbur Stout, David B. Reger, G. H. Ashley, R. C. Moore, and F. B. Plummer. These speakers were not in entire accord, but they presented convincing evidence from Illinois, Ohio, West Virginia, and the northern Mid-Continent region

[1] *Op. cit.*

in favor of many recurring cycles of deposition during Pennsylvanian time.

Groups of fresh-water sand, shale, limestone, clay, and coal beds, alternating with groups of marine shale, limestone, and sandstone, appear repeatedly, according to those speaking for Illinois, Ohio, and West Virginia; also, repetition of a shale and a three-phase limestone sequence is characteristic of the Upper Pennsylvanian of the northern Mid-Continent region as reported by Moore and Condra. Reger stated that ninety-one cycles had been noted in West Virginia, and advocated that the deposits of each cycle be considered as a formational unit. He proposed the "principle of the phantom section," a complete cyclic sequence of which the stratigraphic members absent in any locality are inferred to be present elsewhere.

M. G. CHENEY
A. A. P. G. representative

COLEMAN, TEXAS
May 14, 1930

RESEARCH NOTES

A. A. P. G. RESEARCH COMMITTEE

(Members' terms expire immediately after annual Association meetings of the years shown)

ALEX W. McCOY (1932), *chairman*, 919 East Grand Avenue, Ponca City, Okla.
DONALD C. BARTON (1933), *vice-chairman*, Petroleum Bldg., Houston, Tex.

1931:
K. C. HEALD, 1161 Frick Bldg. Annex, Pittsburgh, Pa.
F. H. LAHEE, Box 953, Dallas, Tex.
R. C. MOORE, Univ. of Kansas, Lawrence, Kan.
F. B. PLUMMER, Bur. Econ. Geology, Austin, Tex.
M. K. READ, 1519 Linda Rosa, Los Angeles, Calif.

1932:
C. R. FETTKE, 1118 Wightman, Pittsburgh, Pa.
A. I. LEVORSEN, Box 1830, Tulsa, Okla.
SIDNEY POWERS, Box 2022, Tulsa, Okla.
R. D. REED, 1110 Glendon Way, Alhambra, Calif.
L. C. SNIDER, 60 Wall Street, New York, N. Y.
W. C. SPOONER, Box 1195, Shreveport, La.
W. T. THOM, JR., Princeton Univ., Princeton, N. J.
F. M. VAN TUYL, School of Mines, Golden, Colo.
W. E. WRATHER, 4300 Overhill Dr., Dallas, Tex.

The purpose of the research committee is the advancement of research within the field of petroleum geology. If members working actively in research on particular problems care to register with the research committee, the committee will be glad to aid them in any way it can and put them in touch with other men who are, or have been, working on similar or allied problems and can perhaps effect some integration of the research work of the Association. If the younger, or older, members of the Association, who are doing or preparing research for publication, will come to any member of the committee, he will be very glad to offer whatever advice, counsel, or criticism he can in regard to the research, its prosecution, or its preparation for formal presentation. The committee would be glad to have members formulate and present to it suggestions in regard to research problems and programs.

RESEARCH COMMITTEE REPORT (1929-1930)

The research committee of the American Association of Petroleum Geologists has attempted to organize and carry on special investigations which will prove of general value to those interested in the problems of oil geology. The committee has not yet seriously considered many research problems of local importance which necessitate special field investigation requiring money. This expansion will come in time with increase in the number of workers and development of finances available for such undertakings. The committee has endeavored not to infringe upon the fields of geological investigation, in problems of applied research, now under way by other organizations.

A fundamental program has been adopted to strike at the basic principles of the science entirely through individual study by the personnel of the research committee and other volunteers, before attempting the expenditure of Association funds.

The question of the relation of oil accumulation to structure is the one paramount problem in every oil-field district. It is a problem that any geolo-

gist searching for oil must consider. Many conflicting theories and ideas of interpretation exist among petroleum geologists. College professors are instructing their students along lines which are accepted generally in the oil profession, regardless of inconsistencies. Are these prevalent ideas really substantiated by the facts? Has the ultimate approximation to the truth been reached? Is the practice of petroleum geology to continue without an increasing accuracy in the interpretation of structural relations to oil accumulation? We believe that acceptance of the present status of affairs as final would not be consistent with the spirit of the workers in this field of science. For this reason, the major effort of the research committee is directed at fundamentals to benefit the greatest number.

The necessary question to be answered is: "Why are oil fields located where they are?" In striving to answer this one question, many side lines or avenues of minor investigation are open for inspection. Correct stratigraphic correlations are necessary for historic analogies. Accurate mapping of outcrops; reliable and complete faunal and floral lists; causes and development of structural processes; principles of historic geology; analytical subsurface water data; and carefully observed facts concerning source material, are some of the many factors which must be considered in approaching the true answer to the one great question. All of these studies should be expanded, if possible. In some problems in connection with which information is materially lacking, it may be necessary for the research committee to authorize appropriations to carry on special work. In dealing with many problems, however, other organizations, with funds for that purpose, will be glad to accept suggestions and follow out investigation along the lines outlined by the Association.

The research committee does not expect to study local problems of one territory to the exclusion of others, nor attempt such local problems if there are other organizations willing to accept that responsibility. Some local problems which materially affect the principal purpose of the research effort must be attempted if there are no other means to accomplish that end.

In order to establish the program of the research committee with a tangible beginning, it was decided in March, 1929, that the individual members of the committee should undertake the analysis of vital problems with present information.[1] This work was begun in 1929. The special chairmen and projects outlined were as follows.

Sidney Powers	Effect of Buried Hills upon Oil Accumulation
F. H. Lahee	Study of Evidences of Lateral and Vertical Migration of Oil
A. I. Levorsen	Importance of Unconformities to Petroleum Geology
Donald C. Barton	Variation of Gravities of Oil with Depth
John L. Rich	Certain Evidences of Origin and Migration of Oil
W. T. Thom, Jr.	Importance of Carbon Ratios to Oil Accumulation
F. B. Plummer	Outline of Present Knowledge with Suggestions Concerning Oil Source Beds
Alex. W. McCoy	Some Methods of Interpretation of Structural Processes

[1] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 7 (July, 1929), p. 878.

At this time these members of the research committee are working on a comprehensive statement of such problems. From these statements many minor lines of investigation will be suggested for individual or collective effort. Volunteers who may be interested in the problems are urged to join this program after these statements have been published and made available to the general membership.

At the New Orleans meeting of the research committee on March 19, 1930, it was recommended that these studies be made available for publication during the year 1930 and that the same be published in one volume as Volume III of the symposium, *Structure of Typical American Oil Fields.*

Reports by F. H. Lahee and Donald C. Barton have been completed and are ready for publication. Other papers are being hurried toward completion. Following the publication of these reports, the research committee expects to expand its endeavors to projects which may help to complete the chain of evidence along certain indicated lines.

During the year 1929 the research committee considered the timely problem of crooked holes. Under the chairmanship of F. H. Lahee, a sub-committee was organized. The report of this committee has appeared in the May number of the Association *Bulletin.*

During the year, two donations to the research fund of the A. A. P. G. were presented: the first, $250.00 by Thomas S. Harrison; and the second, $250.00 by J. Y. Snyder. At present there is $663.86 in the research fund.

Luther H. White was appointed chairman of finances for the research committee, but has delayed active endeavor to raise funds for this work until the research committee can agree upon the most beneficial method of using such funds. This delay has been deemed wise because the research committee does not wish to spend money on problems of minor consequence or localize its expenditures too much for the benefit of any small group within the Association. W. E. Wrather, former chairman of the research committee, reports unpaid old pledges to the amount of approximately $1,400.00. He states that some of these outstanding pledges probably can be collected.

During the year, the stratigraphic correlation studies of Oklahoma and Kansas have progressed admirably under the direction of A. I. Levorsen. Approximately thirty stratigraphic cross sections will soon be available for distribution at reasonable prices. For information concerning the purchase of these cross sections, correspondence should be directed to A. I. Levorsen, Philtower Building, Tulsa, Oklahoma.

The following projects have been formally considered and approved for coöperation and financial assistance when possible, in addition to the regular program as previously outlined.

Project 1: Study of Sedimentation and Correlation of Typical Pennsylvanian Mid-Continent Oil Sands

Submitted by F. B. Plummer

Project 1 is already under way.

Project 2: Compilation of County Maps of Areal Geologic Outcrops of Formations in Texas

Submitted by F. B. Plummer

Project 2 is already under way and several maps are available for purchase from Mr. Plummer, Bureau of Economic Geology, Austin, Texas.

Project 3: Study of the Flora of Typical Geologic Formations with a View to Obtaining Botanical Criteria as an Aid to the Identification of Formations and as an Aid in Geologic Mapping
Submitted by F. B. Plummer

Project 4: A Project Dealing with the Types of Rock Flowage which Might Take Place in Structure of Diapir Type
Submitted by F. M. Van Tuyl

This is a continuation of the experimental work already done by Van Tuyl.

Project 5: Compilation of a Guide to the Index Fossils of Stratigraphic Formations in the United States, Being Sponsored by the Society of Economic Paleontologists and Mineralogists

Project 6: Compilation Study of Structure of the Dakota Sandstone in the Northern Great Plains (North and South Dakota, Montana, and Wyoming) to Ascertain the Growth Stages of Rocky Mountain Orogenic Features
Submitted by W. T. Thom, Jr., and
Carroll E. Dobbin

The research committee has recommended to the executive committee that a committee of three men be appointed to represent the Association on a general committee representing the United States Geological Survey, the Association of State Geologists, the Geological Society of America, and the American Association of Petroleum Geologists, on stratigraphic nomenclature of formations crossing state boundaries.

The research committee has appointed F. B. Plummer and R. C. Moore to outline to the executive committee a plan for raising money for the research fund. The substance of the report of this sub-committee was the recommendation that two funds be established, as follows.

1. A fund of $50,000, composed of sums given anonymously
2. A fund composed of large donations for specific problems or enterprises, each donation to bear the name of the donor

The interest of the first fund, and, with the unanimous consent of the executive committee, the principal of this fund, may be used for financing problems outlined by the research committee, subject to approval by the executive committee. In connection with the second fund, the interest or the principal of any specific donation may be used for designated problems, with the consent of both the donor and the executive committee. The results of research projects supported by these funds are to be printed under direction of the Association.

From time to time the progress of the various research projects will be submitted for publication in the Association *Bulletin* under Research Notes.

A. W. McCoy, *chairman*

Ponca City, Oklahoma
April 11, 1930

REVIEWS AND NEW PUBLICATIONS

RECENT PUBLICATIONS

CALIFORNIA

"Geology and Oil Resources along the Southern Border of San Joaquin Valley, California," by H. W. Hoots. *U. S. Geol. Survey Bull. 812-D* (Supt. Documents, Washington, D. C.), pp. i-vi, 243-338, Pls. 31-48, Figs. 7-9. Price, \$0.50.

FAR EAST

The Mineral Industry of the Far East, by Boris P. Torgasheff. Preface by Wong Wen Hao, director, Geol. Survey of China. The Chali Company, Ltd., 6, Kinkiang Road, Shanghai, China (1930). In English. 500 pp., 270 statistical tables, maps, bibliography. Price, postpaid if remittance enclosed, \$10.00; £ 2.

GENERAL

"Note on Temperature Gradients in the Permian Basin," by Walter B. Lang. *Jour. Washington Acad. Sciences*, Vol. 20, No. 7 (Washington, D. C., April 4, 1930), pp. 121-23.

"Analysis of Oil and Gas from Distillation of Recent Sediments," by Parker D. Trask and C. C. Wu. *Econ. Geol.*, Vol. 25, No. 3 (Urbana, Illinois, May, 1930), pp. 235-41.

GEOPHYSICS

"Depth Attainable by Electrical Methods in Applied Geophysics," by A. S. Eve, D. A. Keys, and F. W. Lee. *U. S. Bur. Mines Tech. Paper 463* (Supt. Documents, Washington, D. C.). 58 pp., 58 figs. \$0.15.

"Theorie der Erdbebenwellen; Beobachtungen; Bodenunruhe," by B. Gutenberg. *Handbuch der Geophysik*, Bd. 4, Lfg. 1 (1929), pp. 1-298, 146 illus. Gebrüder Borntraeger, Berlin. Price, 22 M.

"Seismometer, Auswertung der Diagramme," by H. P. Berlage, Jr. "Geologie der Erdbeben," by A. Sieberg. *Handbuch der Geophysik*, Bd. 4, Lfg. 2 (1930), pp. 299-686, 255 illus. Gebrüder Borntraeger, Berlin. Price, 30 M.

MONTANA

"New Map of Great Falls-Conrad Region, Montana," by C. E. Dobbin and C. E. Erdmann. *U. S. Geol. Survey*, Washington, D. C.; 315 Fratt Building, Billings, Mont.; Shelby, Mont. Free.

WYOMING

"Lithologic Studies of Fine-Grained Upper Cretaceous Sedimentary Rocks of the Black Hills Region," by W. W. Rubey. *U. S. Geol. Survey Prof.*

Paper 165-A (Supt. Documents, Washington, D. C.), pp. i-iv, 1-54, Pls. 1-5, Figs. 1-3. Price, $0.25.

"A Flora of Green River Age in the Wind River Basin of Wyoming," by E. W. Berry. *U. S. Geol. Survey Prof. Paper 165-B* (Supt. Documents, Washington, D. C.), pp. i-ii, 55-81, Pls. 6-15, Figs. 4-6. Price, $0.20.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these applicants, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

FOR ACTIVE MEMBERSHIP

Water H. Hegwein, Tampico, Mexico
    D. Trumpy, W. L. F. Nuttall, W. Tappolet
Robert R. Munoz, New York, N. Y.
    W. E. Wrather, Leon F. Russ, Edwin B. Hopkins
Harold E. Schwartz, Kingsmill, Tex.
    Victor Cotner, Henry Rogatz, George Artman
Edward B. Stiles, Fort Worth, Tex.
    F. W. DeWolf, Sidney A. Judson, Paul Seashore
Henry G. Taylor, Beaumont, Tex.
    R. E. Rettger, N. H. Stearn, L. A. Scholl, Jr.
Addison Young, Midland, Tex.
    Lew Suverkrop, O. C. Harper, H. B. Fuqua

FOR ASSOCIATE MEMBERSHIP

Mildred Virginia Armor, Oklahoma City, Okla.
    V. E. Monnett, Charles E. Decker, G. E. Anderson
Olin D. Brooks, Golden, Colorado
    W. A. Waldschmidt, F. M. Van Tuyl, J. Harlan Johnson
James R. Day, Houston, Tex.
    Lewis W. MacNaughton, Albert E. Oldham, D. R. Semmes
Paul R. Deputy, Los Angeles, Calif.
    E. K. Soper, R. B. Whitehead, R. D. Reed
Francis Gloster Forman, Claremont, Western Australia
    William S. W. Kew, E. M. Butterworth, W. G. Woolnough
Morris E. Halstead, San Angelo, Tex.
    Charles E. Decker, Robert B. Campbell, Allan B. Gray
Bob Hancock, Yale, Okla.
    E. S. Bastin, Carey Croneis, D. J. Fisher
Henry L. Johnson, Iowa City, Ia.
    E. F. Schramm, A. C. Trowbridge, A. C. Tester
Paul H. Kolm, Dallas, Tex.
    M. M. Garrett, H. B. Fuqua, R. B. Whitehead

Paul M. Phillippi, Bradford, Pa.
Robert B. Bossler, L. S. Panyity, A. F. Melcher
Jerome S. Smiser, Princeton, N. J.
W. T. Thom, Jr., W. M. Winton, Gayle Scott
Maria Frances Spencer, Norman, Okla.
Charles E. Decker, V. E. Monnett, C. N. Gould
Garvin L. Taylor, Wichita, Kan.
J. L. Garlough, George H. Norton, Walter A. Ver Wiebe
Edward L. Tullis, Golden, Colo.
J. Harlan Johnson, W. A. Waldschmidt, F. M. Van Tuyl
Thomas E. Wall, Tulsa, Okla.
W. A. Dawson, Robert J. Davis, Frank C. Greene

FOR TRANSFER TO ACTIVE MEMBERSHIP

Clare M. Clark, Calgary, Alta., Canada
J. B. Webb, Delmer L. Powers, Theodore A. Link
Seward F. Harris, Tulsa, Okla.
L. H. White, Robert H. Dott, T. E. Weirich
Kenneth A. Johnston, Los Angeles, Calif.
Paul B. Whitney, Emil Kluth, D. M. Wallace
Paul W. McFarland, Dallas, Tex.
Chas. H. Row, M. A. Harrell, R. F. Schoolfield
Harlan H. Yoakam, Tulsa, Okla.
L. W. Kesler, J. M. Lilligren, C. A. Yoakam

EXECUTIVE COMMITTEE MEETING, NEW ORLEANS, MARCH 22, 1930

The combined executive committees met at the Roosevelt Hotel, New Orleans, Louisiana, March 22, 1930, during the fifteenth annual meeting of the Association. Seven members were present: president J. Y. Snyder of Shreveport, Louisiana; past-president R. S. McFarland of Tulsa, Oklahoma; second vice-president A. R. Denison of Fort Worth, Texas; third vice-president F. H. Lahee of Dallas, Texas; president-elect Sidney Powers of Tulsa, Oklahoma; first vice-president-elect R. D. Reed of Los Angeles, California; and second vice-president-elect Marvin Lee of Wichita, Kansas.

The committee appropriated $1,000 to the Society of Economic Paleontologists and Mineralogists for publishing the *Journal of Paleontology* in 1930.

The invitation of the San Antonio Section of the Association and the San Antonio Chamber of Commerce to hold the sixteenth annual meeting in San Antonio, Texas, was accepted, and March 19, 20, and 21 were selected as the dates for the convention.

It was decided to appoint E. DeGolyer to raise funds for the Association revolving publication fund, and to appoint Luther H. White as chairman of the finance sub-committee of the research committee.

The business manager was instructed to advertise headquarters employment service in the *Bulletin* and to solicit the aid of the U. S. Civil Service

Commission in circularizing the members of the Association about available government positions.

President Powers was empowered to (1) invite the Geological Society of America to hold its annual meeting in 1931 in the Southwest, and (2) offer the coöperation of the Association in planning for the meeting.

Memorial

DANIEL FRANKLIN HIGGINS, JR.[1]

"Mr. Higgins died in Knoxville, Tennessee, on March 21, 1930. At the time of his death he was professor of geology in Lincoln Memorial University, Harrogate, Tennessee. He had been ill for several weeks and the doctors say that his death was really due to the long siege of sickness he had in Egypt ten years ago."

"Mr. Higgins was born in 1884 and spent most of his boyhood in Joliet, Illinois, and was there for a few years, carrying on, in the summer time and during part of the school year, work on the topographic branch of the U. S. Geological Survey,—in fact he began field work with that Survey before he had finished his high school course. He came to Northwestern University for his Senior year, taking his B. S. degree in June, 1907, and his Master's degree in 1909. He also carried on graduate work at the University of Wisconsin and at the University of Chicago."

"Mr. Higgins had wide experience in field work, especially in relation to petroleum. He was for a few years connected with a gold mine in northern Korea, and he was later representative of extensive petroleum work in northern Africa and in Arabia, as well as in Colorado, New Mexico, and Wyoming. He also did geological work in Alaska and in Spitzbergen. He is the author of several papers and his interest in geology was extremely wide. He was an excellent topographer, had an artist's feeling for maps, and his topographic maps expressed sympathetically the underlying geologic structures. He was a member of the American Institute of Mining and Metallurgical Engineers and of the American Association of Petroleum Geologists; also a fellow of the Geological Society of America. During the spring of 1929 he was lecturer on petroleum geology at Northwestern University."

The writer of a very minor part of this memorial became acquainted with Mr. Higgins as a student at Northwestern University, and had the pleasure and profit of working with him in the summer of 1906 in the iron regions of Wyoming, and in 1907 in the lead and zinc region of southwestern Wisconsin. All of his field work was characterized by a high degree of accuracy and excellence. He had a keen appreciation of the beauties of nature; was a genial companion, and an understanding and self-sacrificing friend. His relatives and many friends deeply regret that disease has prematurely taken him from us and from his position as a teacher for which he was so well adapted and fitted by his thorough training and his remarkably wide experience in geological field work.

"In 1910 Mr. Higgins was married to Ethel Nichols Taylor; Mrs. Higgins and two daughters survive him. Funeral services were held at Joliet, Illinois, on March 23, 1930."

CHARLES E. DECKER

NORMAN, OKLAHOMA
April 15, 1930

[1]Most of this information (that part in quotation marks) was supplied by Dr. U. S. Grant, head of the department of geology, Northwestern University, Evanston, Illinois.

AT HOME AND ABROAD

EMPLOYMENT

The Association maintains an employment service at headquarters under the supervision of J. P. D. Hull, business manager.

This service is available to members who desire new positions and to companies and others who desire Association members as employees. All requests and information are handled confidentially and gratuitously.

To make this service of maximum value it is essential that members coöperate fully with Mr. Hull, especially concerning positions available to active and associate members.

Upon recommendation of the research committee of the Association, president Powers has appointed, on behalf of the executive committee, M. G. Cheney, C. J. Hares, and A. I. Levorsen a committee of three to represent the Association on a general committee representing the U. S. Geological Survey, the Association of State Geologists, the Geological Society of America, and the American Association of Petroleum Geologists, on stratigraphic nomenclature of formations crossing state boundaries.

Gerard Henny, formerly of the Shell Company, has opened a consulting office under the name of Henny and Whitmore, petroleum geologists and mining engineers, 649 South Olive Street, Los Angeles, California.

The California State Mining Bureau, at San Francisco, celebrated its fiftieth anniversary, April 16, 1930. The present state mineralogist is Walter W. Bradley.

J. S. Irwin, formerly engaged in consulting practice at Denver, Colorado, is now with the Producers and Refiners Corporation. His address is 1344 Montreal Avenue, Calgary, Alberta, Canada.

R. D. Reed, first vice-president of the A. A. P. G., has an article on "Recent Sands of California" in *The Journal of Geology* for April-May, 1930.

Stephen Rybar, professor and director of the physics department of the University of Budapest and designer of the Eötvös-Rybar torsion balance, and N. Wolff, chief designer of the Süss firm building the same instrument, are in Houston on a business visit to George Steiner.

Stephen Rybar read a paper entitled, "Torsion Wires and Air Currents" on April 18 at a meeting of the Society of Economic Geophysicists in Houston, Texas.

The quarter-centennial celebration of the Illinois State Geological Survey was held, April 30-May 1, at the University of Illinois, Urbana. M. M. LEIGHTON is the present chief.

WALLACE LEE and Miss JEAN MARION FRASER were married, April 23, 1930, at Niagara Falls, Ontario. They are at home at the Lucerne Apartments, Okmulgee, Oklahoma. Mr. Lee is with the Denver Producing and Refining Company.

The seventeenth Oklahoma Field Conference was held in southwestern Kansas and northwestern Oklahoma, April 1-13, 1930, under the auspices of the Oklahoma Geological Survey, CHARLES N. GOULD, director. Permian type sections were studied. Eighty-two men were on the trip.

Geologists using grinding and polishing equipment will be interested in the latest illustrated bulletin issued by E. LEITZ, INC., 60 East Tenth Street, New York, N. Y., on "Apparatus for the Preparation and Examination of Mineral Specimens."

HERBERT E. MUNSON, geologist for The Texas Company in West Texas, with headquarters at Midland, has resigned to accept a position as chief geologist for the Alberta-Pacific Consolidated Oil Company, Ltd., which maintains headquarters at Calgary, Alberta, Canada.

JOSEPH JENSEN, RALPH ARNOLD, and FRANK E. O'NEILL have made a study of the Santa Fe Springs field for the Superior Court of Los Angeles, California.

W. TAPPOLET has charge of the geological work of "La Corona" Oil Company along the Rio Grande.

FRED SHELL has joined the staff of the Prairie Oil and Gas Company at Tulsa.

KARL F. HASSELMANN, formerly of the Standard Oil Company of California, is resident geologist for the North European Oil Corporation, with headquarters in Oldenburg, Germany. CHESTER NARAMORE, of New York City, is president, and A. C. VEATCH, of New York City, is consulting geologist of the Company.

GRADY KIRBY, for many years in the geological department of the Gulf Production Company and recently district geologist at San Antonio, has accepted a position with the Sinclair Oil and Gas Company, and will be in charge of geological work in the Houston district.

W. T. KELLER, who has been at Basel, Switzerland, is now in the employ of the North Venezuelan Petroleum Company, Ltd., Puerto Cabello, Venezuela.

C. J. STAFFORD has resigned his position as district geologist for the Tidal Oil Company in Wichita, Kansas, and has accepted a similar position with the Darby Petroleum Corporation in the Wichita office.

FREEMAN WARD, of Lafayette College, has an article on "The Rôle of Solution in Peneplanation" in *The Journal of Geology* for April-May, 1930.

ANDREW GILMOUR, of the Geophysical Research Corporation, who has been stationed in California for two years, has gone to Ireland on a vacation. On his return he will live at Houston, Texas.

WALDEMAR LINDGREN, of the Massachusetts Institute of Technology, Cambridge, Massachusetts, is chairman of the Organizing Committee of the Sixteenth International Geological Congress.

ARTHUR KEITH, of the National Research Council, will spend the summer in Europe.

ANDREW C. LAWSON, of Berkeley, California, is in England and will return to the United States in the fall.

JULIA GARDNER, of the U. S. Geological Survey, is in Texas working on the new geological map of the state.

W. H. BUCHER, of the University of Cincinnati, announces that his new book, *Laws of Crustal Deformation*, will be published this fall by Princeton University Press.

N. H. DARTON, of the U. S. Geological Survey, will spend the summer in field work in Texas. He is anxious to secure all available information and maps regarding formation boundaries in order that the geological map of the state may be compiled in the fall. Geologists are requested to send such data to him at Washington at once.

M. K. HUBBERT will teach geophysics at Columbia University next year.

G. B. RICHARDSON, of the U. S. Geological Survey, is revising the map of oil and gas fields of Texas.

Miss M. E. LATIMER, of the U. S. Geological Survey, is in charge of securing the location of all wildcat wells in the United States. She would appreciate copies of production maps of districts and of oil fields.

H. F. SMILEY, consulting geologist, of Wichita Falls, Texas, has published *Structure and Stratigraphy of the Wichita Falls Area*, 24 pages, containing a small-scale production map of the area, a cross section extending from Young County to the Electra oil field, and an original cross section of the Bulcher pool, Cooke County. M. G. CHENEY, of Coleman, Texas, has contributed a note, "Pre-Mississippian Production in North-Central Texas." Copies of the pamphlet may be obtained from The Deep Oil Development Company, Wichita Falls, Texas.

R. C. BECKSTROM, head of the school of petroleum engineering of the University of Tulsa, made his second trip to Russia in June.

J. FRENCH ROBINSON, geologist and engineer for the Peoples Natural Gas Company, Pittsburgh, has been elected chairman of the eastern district, division of production, American Petroleum Institute.

CORNELIUS SCHNURR is district geologist for the Mid-Continent Petroleum Corporation at Oklahoma City.

GEORGE I. ADAMS, of the University of Alabama, has an article on "The Significance of the Quartzites of Pine Mountain in the Crystallines of West-Central Georgia" in *The Journal of Geology* for April-May, 1930.

N. H. STEARN, of W. C. McBride, Inc., St. Louis, is in Europe on a business trip.

The National Research Council has authorized Princeton University, the University of West Virginia, and Pennsylvania State College to be permanent depositories for drill cuttings and cores from wells and for well records. The departments of geology of these institutions welcome contributions of material accompanied by complete logs of the wells.

The U. S. Geological Survey has undertaken the compilation of a geological map of the United States to be ready for distribution in 1932.

H. G. FERGUSON, of the U. S. Geological Survey, is chairman of the Committee on Excursions of the Sixteenth International Geological Congress, to be held in Washington in June, 1932. K. C. HEALD, of Pittsburgh, is a member of this committee.

The petroleum sub-committee of the Organizing Committee of the Sixteenth International Geological Congress consists of E. DEGOLYER, *chairman*, W. E. WRATHER, W. E. PRATT, and C. A. FISHER. They will have charge of the program for the petroleum monograph which is to be edited and published by the Association. All matters concerning the participation of the Association will be taken up with them instead of with W. C. Mendenhall, General Secretary.

W. EMBRY WRATHER, consulting geologist, of Dallas, Texas, is in Europe on business.

The third meeting of the International Drilling Congress will be held in Berlin in 1931. It is planned that subsequent meetings shall be held in London in 1933 and in Washington in 1935. ARMAND RENIER, of the Geological Survey of Belgium (Chef du Service Geologique de Belgique), Brussels, has been appointed permanent secretary. The Association is expected to send delegates to these meetings and to offer coöperation in the form of papers.

W. H. TWENHOFEL, of Madison, Wisconsin, announces that a revision of his *Treatise on Sedimentation* is in preparation.

The Annotated Bibliography of Economic Geology, sponsored by Waldemar Lindgren and the National Research Council, is being published and distributed by the Economic Geology Publishing Company, Urbana, Illinois, at a cost to subscribers of $5.00 a year. The second volume for 1929 (July-December) will be published in two months and will contain an extensive bibliography of foreign as well as domestic literature on petroleum geology. Members of the Association are urged to subscribe. (Sidney Powers.)

A comparison of tectonic terms in different languages compiled by G. A. F. MOLENGRAAFF is published in *Geologic Nomenclator*, edited by L. Rutten. 338 pp. (G. Noeff, The Hague, 1929).

The gravimetric and echo-sounding observations near the mouths of the Mississippi River delta and elsewhere made by the Meinesz expedition in U. S. Submarine 21 are in course of publication by the Naval Observatory, Department of the Navy, Washington.

The Committee on Tectonics of the Division of Geology and Geography of the National Research Council asks for coöperation on a transcontinental geological cross section. ARTHUR KEITH has submitted the following memorandum.

I want to suggest a coöperative research project which could be undertaken by oil companies, State geologists, and others. It is a cross section of the United States to be prepared on a horizontal scale of 14,500,000 and such an exaggerated vertical scale as may seem best. It would not be necessary to run an exact straight line across the country, and I would rather have the line go through states where the most information is available. For example, enough is now known of the underground of the Appalachian fields, Ohio, Indiana, and Illinois, to give a good section through those states. Missouri can be sectioned and Oklahoma would give some very interesting information. A section across Wyoming would show that most of the mountain ranges are overthrusts, and this fact is not generally known, but has been worked out by the oil companies and by Professor Knight. Some information is available from oil companies on southern Idaho and a little on the state of Washington. I think that such a cross section would be very useful for the 16th International Geological Congress in 1932 and for the World's Fair in Chicago in 1933.

The University of Texas Bureau of Economic Geology, at Austin, announces receipt of a gift of $900.00 from the Fort Worth Geological Society to be used as the nucleus of a revolving publication fund. The publications issued from this fund will be sold and the proceeds returned to the fund, thus providing for additional publications. The first publication to be issued from the fund will be *Geology of the Glass Mountains of Texas*, by PHILIP KING.

The Shell Petroleum Corporation has closed its geological offices at Shreveport, Louisiana, and at Wichita Falls, and Coleman, Texas.

SCHUYLER B. HENRY, of the geological staff of the Standard Oil Company of California, has been placed in charge of exploratory work to be conducted in Colombia, through the Richmond Petroleum Company, a subsidiary.

D. M. WALLACE is in charge of land operations in Texas and New Mexico for George F. Getty, Inc., with offices in the Electric Building, Fort Worth.

PAUL WEAVER spoke on "Formations of Large Salt Deposits" at the weekly luncheon of the Houston Geological Society, May 6.

W. W. PATRICK, geologist for The Texas Company, has been transferred from the division office at Fort Worth to Midland, Texas, where he will have charge of the West Texas and New Mexico district activities of the geological department.

CHARLES SCHUCHERT, of Yale University, New Haven, Connecticut, has an article entitled "Synopsis and Discussion of Lauge Koch's Geology of Greenland" in the May issue of the *American Journal of Science*.

Mr. and Mrs. DON DANVERS, San Antonio, Texas, have returned from a trip to Panama. Mr. Danvers is geologist and district manager for the Sinclair Oil and Gas Company at San Antonio.

GEORGE S. HUME, of the Geological Survey of Canada, Ottawa, has an article on "Oil and Gas Developments in Western Canada During 1929" in the April issue of the *Journal of the Institution of Petroleum Technologists*.

JAMES C. TEMPLETON, consulting geologist and geophysicist, has returned to London from Venezuela, where he has been carrying out a geophysical survey of the properties of the British Controlled Oilfields, Ltd.

KATHERINE ELIZABETH WORTHINGTON is a consulting paleontologist with offices at 1618 Milam Building, San Antonio, Texas.

JULIAN W. SMITH is chief geologist for the Eason Oil Company at Enid, Oklahoma.

Mr. and Mrs. FRED M. BULLARD, Austin, Texas, announce the birth of a daughter, Margaret Rhea, born February 8, 1930.

EARL M. STILLEY is president of the Grayback Development Company at Wichita Falls, Texas.

The San Antonio Section of the A. A. P. G. held its regular monthly meeting, May 5. ALVA CHRISTINE ELLISOR, of Houston, Texas, presented a paper on "Correlation of the Jackson Formation in Texas." The meeting was attended by approximately eighty geologists from the San Antonio district. A cordial invitation is extended to visiting geologists to attend these meetings, which are held on the first Monday of each month at the San Antonio Petroleum Club rooms in the Milam Building. An invitation is also extended to attend the weekly luncheons which are held each Monday noon at the same place.

JOHN T. STUBBS, of Lake Charles, Louisiana, is with the Apure Venezuela Petroleum Corporation, 1 Plaza Flores, Puerto Cabello, Venezuela.

LAWRENCE P. SPENCER has left the Skelly Oil Company at Wichita, Kansas, to take a position as geologist with W. C. McBride, Inc., McPherson, Kansas.

The committee on methods of election of officers has been selected by the executive committee and appointed by president POWERS as follows: *chairman*, W. E. WRATHER, 4300 Overhill Drive, Dallas, Texas; *vice-chairman*, H. B. FUQUA, Gulf Production Company, Fort Worth, Texas; FRANK S. HUDSON, 1625 Opechee Way, Glendale, California; W. B. HEROY, Sinclair Exploration Company, 45 Nassau Street, New York City; R. E. DICKERSON, Venezuelan Atlantic Refining Company, Apartado 223, Maracaibo, Venezuela; A. F. CRIDER, 821 Ontario Street, Shreveport, Louisiana; J. V. HOWELL, 300 North

Fourth Street, Ponca City, Oklahoma. Mr. Fuqua will head the committee this summer while Mr. Wrather is in Europe, and members of the Association are invited to submit suggestions to him.

U. R. LAVES, formerly with the Tidal Oil Company at Tulsa, is now geologist for the Southwest Gas Utilities Corporation. His address is 706 East Fifteenth Street, Ada, Oklahoma.

E. C. EDWARDS has resigned his position as Texas manager of the Superior Oil Producing Company. Mr. Edwards has been located at the company's Texas headquarters in San Angelo. He is now making his residence in Monrovia, California.

W. G. WOOLNOUGH, government geologist for Australia, is making an extended visit to oil fields in North and South America after attending the New Orleans meeting of the Association.

ELI T. MONSOUR has resigned from the Humble Oil and Refining Company at Houston, Texas, effective June 1, and has accepted a position as paleontologist for the Compañia de Petroleo Mercedes, S. A. His address is Apartado 269, Monterrey, Nuevo Leon, Mexico.

T. M. RAGSDALE is geologist for the Magnolia Petroleum Company at San Antonio, Texas.

H. HARPER MCKEE, of New York City, has a district office in the Milam Building, San Antonio, Texas.

R. J. RIGGS, in charge of the land and geological departments of the Indian Territory Illuminating Oil Company, has returned to Bartlesville, Oklahoma, after spending the winter in San Antonio, Texas.

GEORGE C. MATSON, consulting geologist, Tulsa, Oklahoma, has his office in the Philcade Building.

HUGH DICKSON, formerly with the Amerada Petroleum Corporation, is now scout and geologist for the Producers and Refiners Corporation at Ardmore, Oklahoma.

JOE PALMER is geologist for the Southern Crude Oil Purchasing Company at San Antonio.

L. W. STEPHENSON, of the U. S. Geological Survey, Washington, D. C., has been mapping the Cretaceous in central Texas.

ARTHUR L. HAWKINS, geologist for the past eight years for the Transcontinental Oil Company, has resigned and has opened an office in Denver, Colorado.

E. R. LILLEY, of the department of geology of New York University, will study political and commercial policies regarding mineral resources in Europe for a year, with the aid of a fellowship from the John Simon Guggenheim Memorial Foundation.

The Gunter Hotel has been selected as headquarters for the sixteenth annual meeting of the A. A. P. G., at San Antonio, Texas, March 19-21, 1931.

W. T. THOM, Jr., has resigned from the U. S. Geological Survey, and plans to begin work in June on parts of the A. A. P. G. research project covering the regional structure of the Dakota sandstone in the Northern Plains region.

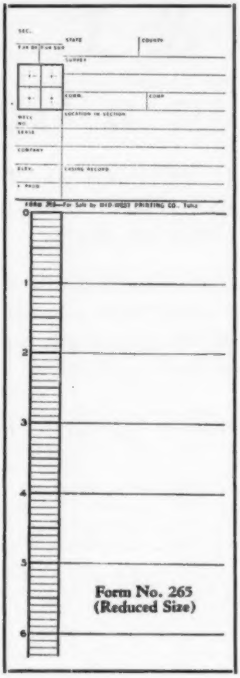
C. L. DAKE, of the Missouri School of Mines, Rolla, Missouri, presented a paper on "Structural History of the Ozark Uplift" before the Tulsa Geological Society, May 19, 1930.

Preliminary announcement of the results of the recent vote on the revised constitution shows that the amendments were carried by a large majority. A detailed statement of the returns will be made in a later *Bulletin*. The complete constitution and by-laws as revised and now in effect were printed in the *Bulletin* for May, 1930, pages 671-77.

B. L. THORNE is mining engineer for the Department of Natural Resources, Canadian Pacific Railway, Calgary, Alberta, Canada.

STEPHEN WHITE BROCK, San Angelo, is district geologist in West Texas for The Pure Oil Company.

A. W. AMBROSE, for many years in charge of the production department, has been elected to the vice-presidency of the Empire Oil and Refining Company, Bartlesville, Oklahoma.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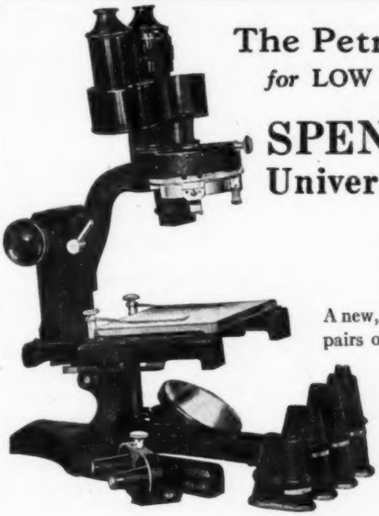

Pet. D. & T., 1930 Comes in a Gusher

PETROLEUM DEVELOPMENT AND TECHNOLOGY, 1930, covers all phases and all oil fields in the world.

So rich are the data and detail so timely, and with so much force of authority, that no one in the petroleum industry can well afford to be without it.

UNITIZATION: "The Institute is a forum for discussion." Unit operation of oil pools was thoroughly threshed out at several sessions. The Report of the Committee, and regional reports for foreign countries, Eastern United States, Oklahoma, Kansas, Gulf Coast, Rocky Mountain Region, and California, by H. H. Hill, E. L. Estabrook, A. W. Ambrose, C. E. Beecher, F. H. Lahee, F. E. Wood, W. B. Emery, N. T. Nightingale, Joseph Jensen are given; with pertinent discussion by G. O. Smith, H. L. Doherty, L. L. Brundred, R. R. Boyd, H. C. George, J. M. Lovejoy, F. J. Fohs, J. E. Pogue, C. P. Watson, J E. Thomas, E. R. Lilley et al.; also **"Principles of Operation,"** by Earl Oliver and J. B. Umpleby.

PRODUCTION ENGINEERING: Chapters on Well Spacing, Gas-Oil Ratios, Hydraulics of Flowing Wells, Increasing Extraction, Valuation, and other subjects, are presented by L. C .Uren, J. Versluys, P. P. Gregory, R. A. Hancock, G. V. Feskov, S. F. Shaw, F. P. Donohue, R. W. Bond, D. L. Trax, C. D. Watson, M. Walker, A. H. Bell, F. W. Webb, C. M. Nickerson, C. R. Fettke, P. D. Torrey, H. C. Otis, H. C. Price, H. J. Morgan, J. Jensen, M. D. Graves, W. D. Gould, M. L. Gwin, E. A. Stephenson, I. G. Grettum, S. C. Herold; with discussions.

PRODUCTION statistical reports for 1929 for practically every producing area in the world are available in this book. Particularly valuable and timely is the Kansas report by Straub and Folger.

RESEARCH in Oil Recovery, Cementation, Drilling, and Corrosion, is described by H. D. Wilde, Jr., F. W. Hertel, E. W. Edson, L. G. E. Bignell, I. I. Gardescu, W. F. Cloud, W. Shriever, J. Chalmers.

ECONOMICS is covered by W. A. Sinsheimer, J. E. Pogue, H. J. Struth, J. E. Thomas and B. Bryan; Summaries on Refining and on Engineering Education are given by A. D. David and H. C. George.

These papers were presented at the Tulsa (October), Los Angeles (October), and the New York (February) meetings and are accompanied by the discussion. As usual, there is an excellent index containing subjects and authors in one alphabetized list.

The timeliness of these papers makes them of such immediate value to you, that we urge you to obtain this volume at once.

The Secretary,
A.I.M.E.
29 W. 39th St.,
New York

Enclosed is $..................
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